JOURNAL OF THE AERONAUTICAL SCIENCES

VOLUME 3 NUMBER 7

MAY, 1936

Published by the

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VOL. 3 MAY, 1936 NO. 7

Editor: J. C. HUNSAKER, *Massachusetts Institute of Technology*

PUBLISHED MONTHLY BY THE INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.
AT 99–129 NORTH BROADWAY, ALBANY, NEW YORK

The JOURNAL OF THE AERONAUTICAL SCIENCES is the official publication of the Institute of the Aeronautical Sciences, Inc., and is devoted to papers on experimental, theoretical, and applied science as employed in aeronautics.

Manuscripts for publication, proofs, and all correspondence should be addressed to the Editorial Secretary of the JOURNAL. Subscription price: $5.00 per year; single copies, 50c. Foreign subscription price: $6.00 per year; single copies, 60c.

Correspondence regarding subscriptions may be addressed to Publication Office, 99–129 North Broadway, Albany, N. Y., or to the Editorial Office of the JOURNAL OF THE AERONAUTICAL SCIENCES, 5431 R. C. A. Building, Rockefeller Center, New York, New York. Cable Address: INSAEROSCI.

Entered as Second Class Matter at Post Office, Albany, N. Y., October 2, 1935. Acceptance for mailing at a special rate of postage provided for in the Act of October 3, 1917, embodied in paragraph 4, section 412, P. L. & R. authorized February 17, 1934.

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JOURNAL OF THE AERONAUTICAL SCIENCES

Volume 3 MAY, 1936 Number 7

Graphical Calculation for Continuous Beams

LEO KIRSTE, *Blériot-Aeronautique, Suresnes (Seine)*

(Received November 10, 1935)

SUMMARY

COMPUTATION of bending moments resulting from pure bending and axial compression becomes very cumbersome, if not impossible, as soon as the moments of inertia and the distributed and axial loads vary along the span. A graphical method, based on the trial-and-error principle, has been published by Barbara Gough in R. & M. No. 741. The present paper gives a more general solution of the problem, applicable to practical cases. It is based on the separation, even in the case of axial compression, of the "Bay Moments" and the "Support Moments" and adding them, after their having been "amplified" by additional moments, corresponding to distributed loads of magnitude MP/EI.

The principle of a graphical method, giving the resultant bending moments in a girder subjected to combined flexure and buckling, has been published in N.A.C.A. T. M. No. 305, of March 1925. In order to generalize this method, and extend its application to continuous girders, we make use of the possibility of adding, arithmetically, bending moments and deflections produced by independent transverse loads.

The "amplifying" effect of the longitudinal loads can best be represented by an imaginary transverse load, the magnitude of which is, at each point, $r' = M_1 P/EI$. In this expression, P is the longitudinal load (positive if compression), M_1 the resulting bending moment. It is obtained by adding to the bending moment M, produced by the transverse loads alone, the infinite series of moments

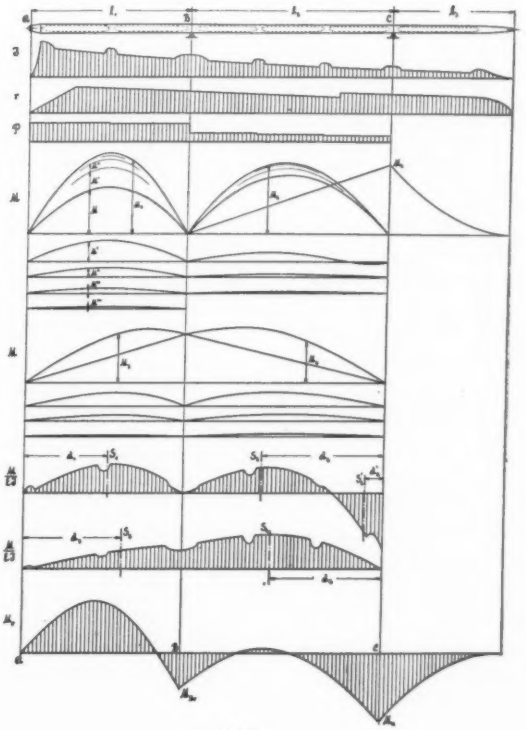

FIG. 1

$$M' + M'' + M''' + \ldots\ldots$$

corresponding to the successive loads

$$MP/EI, M'P/EI, \text{ etc.}$$

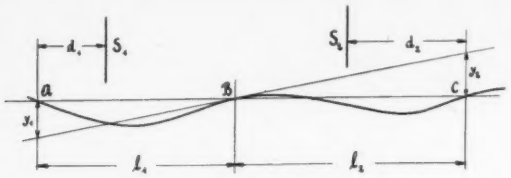

FIG. 2

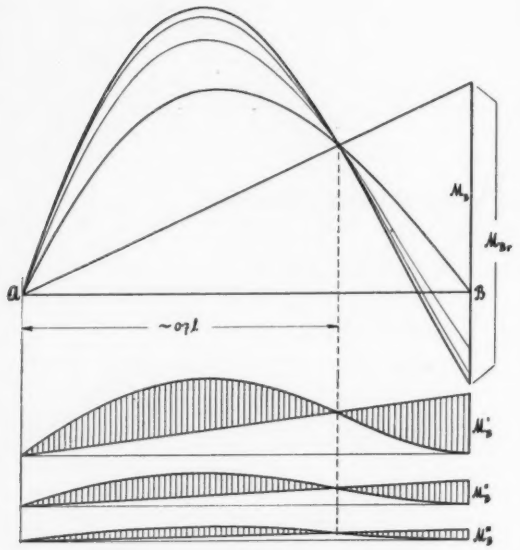

FIG. 3

The procedure indicates that it will be possible to subdivide the initial bending moment in any way, make the graphical operations separately on each part and then add the partial resulting moments; the only condition will be that the "amplifying factor" P/EI conserves its same value at each point.

In Fig. 1 this method has been applied to a two-bay girder. It shows, beginning from the top: The given moments of inertia, transverse and longitudinal loads; then, the bending moments in each bay (M). Multiplying M by P/EI gives the additional loads, hence the bending moment M'. Repeating this procedure leads to the bending moments M'', M''', etc., the addition of which gives the resulting moment M_1.

The same method is applied to the moment curve produced by the moments on the supports, starting with an arbitrary value (10.000 cm. kg) at B. Amplifying by the longitudinal loads gives the resulting bending moments M_3 and M_4. The correct value of M_B can now be found by a simple "rule-of-three". With the notations of Fig. 2 the expression for continuity of the elastic curve over the support B may be written:

$$(-y_1) : y_2 = l_1 : l_2; \quad l_2 \cdot y_1 + l_1 \cdot y_2 = 0$$

The deflection y_1, measured from the tangent at B being:

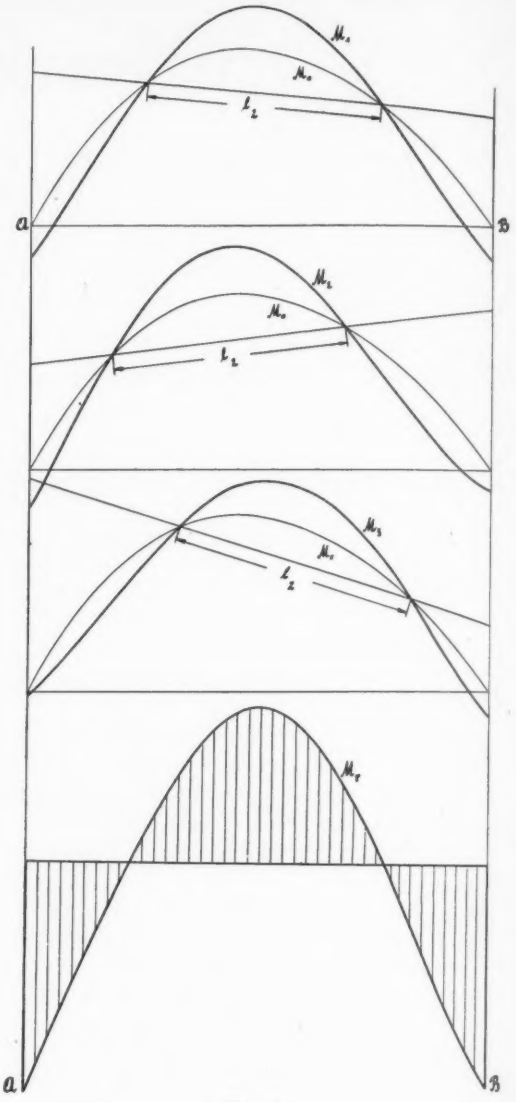

FIG. 4

$$y_1 = \int_o^l \int_o^l M/EI \cdot dx \cdot dx = S \cdot d,$$

where $S = \int_o^l M/EI \cdot dx$ = area of moment curve, divided by EI, and ol = the distance of its centre of gravity from the support A. In the case represented by Fig. 1, there are two moment areas in each bay, one corresponding to the transverse loads alone, the other to the moments at the supports; the indices show the correspondence. The condition of continuity becomes:

$$l_2\left(S_1 d_1 - \frac{M_B}{10.000} S_3 d_3\right) + l_1\left(S_2 d_2 - S'_2 d'_2 - \frac{M_B}{10.000} S_4 d_4\right) = 0$$

Hence:

$$M_B = 10.000 \frac{l_2 S_1 d_1 + l_1 (S_2 d_2 - S'_2 d'_2)}{l_2 S_3 d_3 + l_1 S_4 d_4}$$

The curve of resulting bending moments can now be traced completely.

The convergency of the infinite series of values MP/EI becomes unsatisfactory if the longitudinal loads approach the critical value for buckling. If this value is attained, the two series become of infinite value and the resulting moment appears under the form $\infty - \infty$.

Nevertheless, its value may be quite finite, for the critical load of a bay, being part of a continuous girder, can be much higher than that of the same bay being simply supported. With one or two fixing moments, one or two points of contraflexure may occur in the bay, thus reducing the "free crippling length" to 70 or 50 per cent, and increasing the critical limit of buckling to twice or four times its original value.

Taking account of this circumstance does not complicate the application of our graphical method; the example in Fig. 1 has only been chosen to make comprehension easier.

It would not be sufficient to add negative moments of arbitrary value at the supports. These moments must be amplified at the same time as the others. Fig. 3 shows the case of a single point of contraflexure, located at about 70 per cent from the pin-jointed support. Its position must be maintained throughout the consecutive operations; the bending moment at this point must be reduced to zero by adding appropriate moments M'_B, M''_B, etc., at the clamped support. The exact position of the point of contraflexure being unknown to start with, the graphical calculation has to be made for two slightly different positions, giving the resultant moments M'_1 and M''_1, and the static moments $S'_1 d'_1$ and $S''_1 d''_1$. The final values may be expressed by

$$M_1 = M'_1 + (1-x) M''_1 ; \quad S_1 d_1 = S'_1 d'_1 + (1-x) S''_1 d''_1$$

The expressions for the adjacent bay are

$$M_2 = M'_2 + (1-y) M''_2 ; \quad S_2 d_2 = S'_2 d'_2 + (1-y) S''_2 d''_2$$

hence the condition of continuity

$$M'_1 + (1-x) M''_1 = M'_2 + (1-y) M''_2 l_2$$
$$\times \{S'_1 d'_1 + (1-x) S''_1 d''_1\} + l_1 \{S'_2 d'_2 + (1-y) S''_2 d''_2\} = O$$

x and y being the only unknowns. Elimination of these gives the final values of M_1 and M_2.

As a last example, let us consider a single bay, clamped at both ends. There will be two points of contraflexure and the graphical calculation has to be made for two different positions of each of them, that means three times in all (Fig. 4). Owing to the clamped supports at both ends, there will be neither deflection nor rotation of one end with respect to the other, therefore

$$\Sigma S = O ; \quad \Sigma S d = O$$

Taking the values $S'\ d'$, $S''\ d''$ and $S'''\ d'''$ resulting from the graphical calculations, we have

$$x S' + y S'' + (1-x-y) S''' = O ;$$
$$x S' d' + y S'' d'' + (1-x-y) S''' d''' = O$$

These two equations determine x and y; the final moment is:

$$M = x M' + y M'' + (1-x-y) M'''$$

The described graphical method presents distinct advantages over the analytical methods so far employed: It is absolutely "general", allowing for variation of moment of inertia, transverse and longitudinal loads, not only from one bay to the other, but from point to point; its application involves only very simple manipulations, making it especially useful for design work.

Book Reviews

Gli Scritta di Leonardo da Vinci sul Volo (The Works of Leonardo da Vinci on Flight), by R. GIACOMELLI, with a preface by GENERAL CHRISTOFORO FERRARI; Dott. G. Bardi, Rome, 1936; 367 pages.

This book in Italian is a compendium of the writings of Leonardo da Vinci. With painstaking thoroughness Dr. Giacomelli has collected all of Leonardo's writings, analysed them in the light of modern knowledge, and clarified many hitherto obscure statements. The great Italian reversed the usual process of aeronautical investigation. He first devoted his study to the mechanical means of flight and later observed and described in great detail the flight of birds.

Practical Performance Prediction of Aircraft, by LT. COL. J. D. BLYTH; The Pitman Publishing Corporation, New York, 1936; 80 pages, $1.50.

This new volume of the aeronautical engineering series gives a brief and concise account of performance prediction. Projected designs can be readily outlined by the methods given. While short, the book is self-contained and any reader with a knowledge of the fundamentals should be able readily to acquire a practical working knowledge of the subject.

Trends in Longitudinal Stability

OTTO C. KOPPEN, *Massachusetts Institute of Technology*

(Received February 29, 1936)

ON questions of flying characteristics the pilot and designer invariably do not speak the same language, and longitudinal stability is no exception to this unfortunate condition. The designer's measure of longitudinal stability is the moment obtained for a given change of angle of attack; the greater the change of moment, the greater the stability. The pilot's yardstick of stability, however, is the rate at which the airplane returns to its equilibrium attitude after a disturbance. The two criteria do not lead to the same results, and often an increase in what the designer calls stability merely annoys the pilot by an increase in control force without any beneficial effect upon the airplane motion.

In fairness to the airplane designer, it must be admitted that his criterion is fairly satisfactory to distinguish between stability and instability, and at present that appears to be sufficient for practical purposes, since no attempt is made to determine the degree of stability of airplanes. However, the slope-of-the-pitching-moment curve cannot be used as a measure of stability; it is only a qualitative guide.

The curve on Fig. 1 was drawn to demonstrate this fact. It represents the variation of the period of longitudinal motion with tail size for a typical airplane. As the tail size was changed, the center of gravity location was also shifted so as to maintain a constant slope-of-the-pitching-moment curve. An examination of this curve shows that it makes a considerable difference in the airplane motion whether a large or small tail is used. With the small tail the airplane is quite stable, but at the other end of the scale, the airplane approaches what the pilot would probably call neutral stability. However, according to the designer's criterion, the stability is constant and the difference in tail size is immaterial.

The fundamental difficulty with this longitudinal stability yardstick is that it reduces the motion of the airplane to one having a single degree of freedom, and further assumes that damping is zero. Unfortunately, however, the idealized motion assumed by the designer does not even approximate the actual motion and, consequently, quantitative estimates made by that method are meaningless.

To include all of the variables involves a considerable amount of arithmetical work, but charts similar to those given in R. & M. No. 1118 and N.A.C.A. T. R. No. 521 may be used to reduce the amount of labor involved. The writer has found that the following grouping of

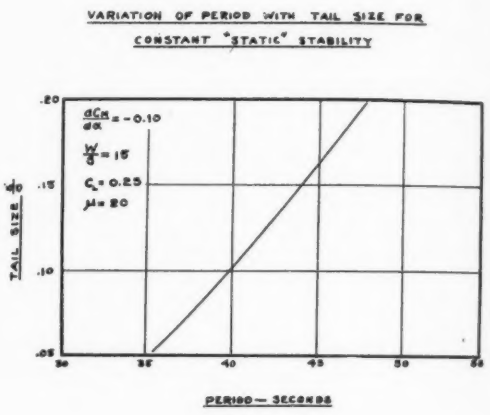

FIG. 1

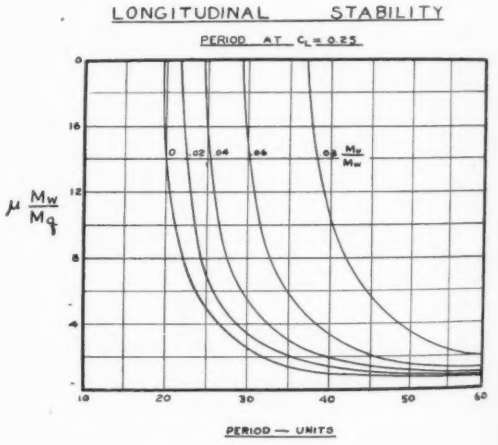

FIG. 2

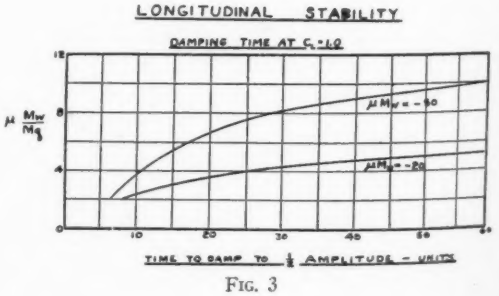

FIG. 3

the variables and the resulting curves is most convenient. The parameters used are the two introduced by Glauert in R. & M. No. 1093:

$$\mu = \frac{\frac{W}{S}}{\frac{\rho}{2} gL}, \quad T = \frac{\frac{W}{S}}{\frac{\rho}{2} gV}$$

and, in addition, two more that combine all of the moment variables in the system:

$$M_w/M_q,\ M_u/M_w$$

The first parameter might be called the airplane density and depends on the ratio of wing-loading to length; the second is the time unit of the system; the third is the ratio of the slope-of-the-pitching-moment curve to what might be described as the tail effectiveness; and the fourth is the ratio of the change of moment coefficient with forward speed to the slope-of-the-pitching-moment curve.

The curves on Fig. 2 show the effects of changes of these parameters on the motion. The immediate conclusions from these curves are that the ratio of the change of moment coefficient with forward speed to the slope-of-the-pitching-moment curve should be as small as possible, and that the product of μ and the ratio of the slope-of-the-pitching-moment curve to the tail effectiveness should not be too large.

To proportion the airplane for longitudinal stability, the designer has three quantities to deal with, namely: The center of gravity location relative to the wing aerodynamic center; the size of the tail; and the moment coefficient of the wing. His object should be to get the desired airplane motion without interfering with the controllability of the airplane. Consequently, M_w should be as small as possible. This means that the tail will be small since the ratio of M_w/M_q is fixed by the period required.

If no other check is made upon the proportions so obtained, there is a possibility that the damping of the motion at high angles of attack will be poor. Therefore, an additional set of curves is needed to determine the degree of damping. This family of curves is based on the variables μ (M_w/M_q) and μM_w and is plotted against the time required to damp the motion to one-half amplitude. Fig. 3 is an example of this type of plot and the curves shown include the normal variation of μM_w.

High Altitude Transport

Presented at the Aircraft Operations Session, Fourth Annual Meeting, I. Ae. S.

W. C. ROCKEFELLER, *California Institute of Technology*

DURING the past year considerable interest has been evidenced in the possibilities of flight at altitudes up to and above the base of the stratosphere. Most of this interest has centered around commercial transportation at these altitudes, particularly over long distances. Many conflicting claims have been made concerning the practicability and possible advantages of such high altitude flying, and it is therefore desirable to make an engineering analysis of the problem in order to determine the potential speeds and operational requirements which may be expected.

In this paper the author will consider only conventional planes with the addition of extreme supercharging and pressure cabins, and attention will be confined to only two phases of the subject. First, an aerodynamic analysis will be made, from which a basis for comparison with flight at the lower altitudes can be established. Second, since for airline operation meteorological influences are of prime importance, this phase of the problem will be considered.

First consider the potential speeds which can be realized with the modern aircraft supercharged to high altitudes. In Fig. 1 there is presented a series of curves showing the speed in level flight as a function of altitude. The values for these curves have been calculated by an as yet unpublished method analogous to that of W. B. Oswald (N.A.C.A. Technical Report 408) except that the equations and charts derived are based on constant thrust horsepower available. The quantities Λ and l_t are as defined by Oswald. Curve (3) corresponds to the full power operation of an airplane similar to the Douglas DC-2 Transport but with additional supercharging. Curves (1) and (2) give similar speeds for cruising at 65 and 75 per cent power as indicated. Since in airline operation cruising must form the basis for any comparison, these latter two curves must be used to compare speeds at high altitudes with those at low altitudes. It will be noticed immediately that for an airplane of this type, cruising at 65 per cent power, which is common practice on several of the present airlines, the advantage in speed gained from high altitude flight is comparatively small and probably would not justify the engineering and constructional complications entailed. Therefore, if flight at high altitudes is to prove advantageous, the power loading must be decreased. If, then, the present full power is considered to be the future cruising power, Curve (3) will be the one which will interest the airline operator. Curve (4) gives the full power speeds assuming Curve (3) to represent 70

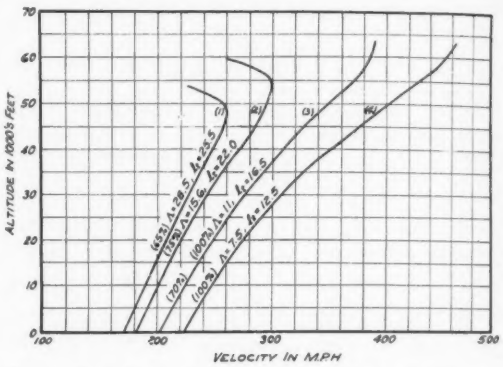

FIG. 1. Velocity *vs.* altitude for level flight for representative airplanes.

per cent, or cruising, power. Curve (3) will be taken as the basis for the comparison. (The above assumes that the power is maintained, by proper supercharging, to the altitudes indicated.)

Next, consider the altitudes at which these proposed airplanes must fly. There are three regions of altitude which can be classified by physiological reactions. For the first region, from sea-level to 15,000 feet, the passengers will require neither oxygen nor supercharging in the cabin. For the second region, 15,000 to 25,000 feet, no supercharging will be required, but additional oxygen must be supplied to the cabin in order to maintain the oxygen density at the proper level. At 30,000 feet, in order to maintain this oxygen density, the atmosphere within the cabin must be pure oxygen. Therefore, to go above this altitude, it will be necessary to supercharge the cabin. The third region of altitude, then, will be that above 25,000 feet, where there must be complete cabin supercharging.

Airline operation is concerned not with air speed at a given level, but with the so-called block-to-block time. Thus the climb and glide incident to the flight must be considered. The rates of climb and glide will be governed by three factors: Physiological, aerodynamic, and structural limitations. In regard to the physiological limitation, it may be said that the rate of change of pressure experienced by the passenger should not exceed values corresponding to a climb of 500 feet per minute or a glide of 300 feet per minute. These limits are in agreement with the present recommendations of the Department of Commerce for airline practice. Therefore, if the cabin remains unsupercharged, these become the limits of the climb and glide. Next, as to the aerodynamic limitations, an analysis will show that

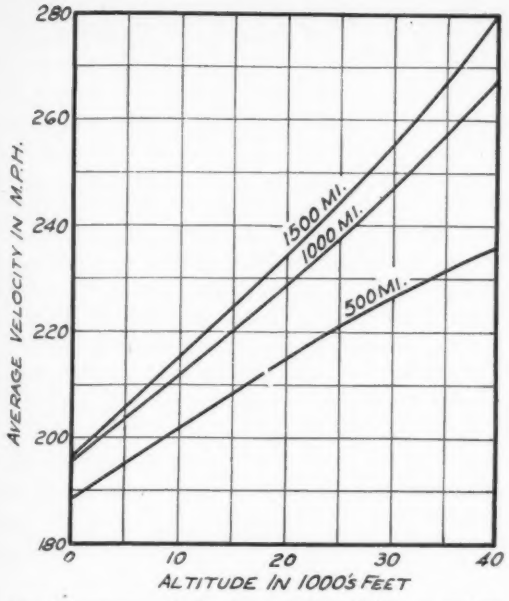

FIG. 2. Average velocity for complete flights at various altitudes.

the best rate of climb is one somewhat higher than the maximum for passengers' comfort, and the maximum rate of glide should be much higher than the limit for passenger comfort, that is, of the order of 1500 to 2000 feet per minute. The third factor is the structural limitation. This introduces no difficulty during the climb. However, during the glide the airplane must be restricted to a rate of glide such that the dynamic pressure, or indicated air speed, does not exceed a certain allowable value inherent in the design. These factors, then, will affect the efficiency of the flight in the following manner: For a ship equipped with no cabin supercharging, the climb and glide will be limited by the physiological factor. Thus the efficiency in climb and glide is greatly impaired for this type of ship. With cabin supercharging, the limit on the climb will be imposed by the aerodynamic considerations, thus giving the greatest efficiency, while on the glide the limits will, in general, be due to the structural factor, thus approaching the most efficient operation more closely than in the case of the unsupercharged cabin.

From the above considerations, it is evident that an airplane with supercharged cabin would be most desirable from the standpoint of efficiency, efficiency being here defined to imply economy in time only. Assuming such an airplane and using average values for the time taken by taxiing, take-off, and landing, in addition to that for the climb, intermediate flight, and glide, a series of curves, Fig. 2, was calculated indicating the average speeds, block-to-block, which might be realized for flights over the three distances shown at altitudes indicated as abscissae. An average value of time taken for taxiing, take-off and landing, and maneuvering to and from 500 feet altitude was assumed to be ten minutes. This value represents a statistical average of data obtained by many investigators from actual schedule studies. The times and speeds for climb and glide were calculated by standard performance methods. It is immediately apparent that a considerable gain in average speed is possible at the higher altitudes for the greater distances. However, the airline operator is interested not in average speed increases, but more directly in actual time saved in comparison with flight at the lower altitudes. Fig. 3 shows this comparison. The altitudes at which the proposed flights are to be made with a supercharged cabin airplane are plotted as the abscissae, and time saved is plotted as the ordinate. To find the time which will be saved by flying at a higher altitude with a pressure cabin instead of at sea-level, 15,000 feet, or 25,000 feet with a pressure cabin, enter the chart with the altitude in question going vertically to the solid curve labeled with the altitude of the ship with which the comparison is to be made. The corresponding ordinate gives the time saved. To compare the proposed supercharged cabin ship with one which is unsupercharged and flying at 15,000 or 25,000 feet, use the broken curves instead of the solid curves. For example, for a 1000 mile flight, the time saved by flying at 40,000 feet with a supercharged cabin instead of at 25,000 feet with a supercharged cabin is 27 minutes, and that saved in comparison with a ship flying at 25,000 feet with an unsupercharged cabin is 37 minutes. Some study of the chart will show that for flights of 500 miles or less, there is little to be gained from flights above 15,000 feet; but for distances of 1000 miles or over, considerable advantage is evidenced for flights at these higher altitudes.

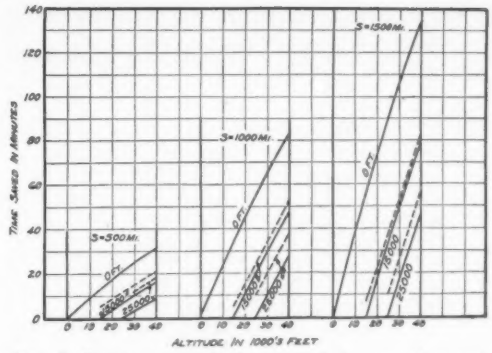

FIG. 3. Comparison of time saved in carrying out specific flights at various altitudes.

The above analysis immediately suggests an important question. Over what distances are flights at high altitudes, say 40,000 feet, justified? Fig. 4 indicates the elapsed time for a proposed 3000 mile trip at 40,000 feet with a pressure cabin, to be made in a series of flights of lengths indicated along the abscissa. These curves have been calculated with proper allowance for ground time, take-off, and landing for each of the stops, in addition to the time required by the actual flight proper. Fifteen minutes were allowed on the ground

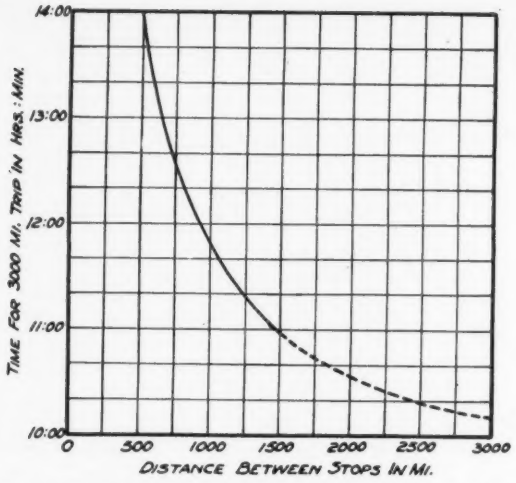

FIG. 4. Comparison of elapsed time for 3000 mile trips at 40,000 feet with varying distances between stops.

at each stop. The figure shows that 1000 mile flights and possible 1500 mile flights will contribute a considerable time saving over shorter flights, but the extension to longer individual flights, say non-stop, would apparently not be justified for economic operation, especially when consideration is taken of the reduced payload required by the great fuel weight necessary.

From the aerodynamic considerations, then, the following conclusions are reached:

(1) Flight should be restricted to altitudes below 15,000 feet for flights of 500 miles or less.

(2) Flight at altitudes of 15,000 to 25,000 feet is advantageous over distances of 500 to 1000 miles.

(3) Flight at altitudes above 25,000 feet should be justified for distances of 1000 to 1500 miles.

(4) Flights longer than 1500 miles are apparently not economically justified at altitudes of 40,000 feet or less for trips of 3000 miles.

The above conclusions are a result of the aerodynamic, physiological, and structural factors only. The meteorological factors must now be considered.

First, consider the winds that may be expected at the higher altitudes. In general, it can be stated that for the mid-latitudes, the westerly component of the wind, that is, blowing from west to east, will increase with altitude up to approximately the level of the base of the stratosphere, or about 40,000 feet. Above this level a decrease in the westerly component will be observed, and the winds will actually become east winds at extremely high altitudes, of the order of 60,000 feet. Thus the maximum west wind will occur near the base of the stratosphere. The normal magnitude of these winds at 40,000 feet is approximately 60 to 70 m.p.h., but this really represents a mode of the frequency of occurrence of these velocities rather than an average. Therefore much higher velocities, say 120 to 150 m.p.h., can be expected frequently. This, coupled with the fact that these winds are practically unforecastable unless a considerable extension of wind data is realized, makes it apparently essential that east-bound flights be made at the high altitudes and west-bound flights at the lower altitudes. This becomes a very serious restriction to be imposed on the design of a high altitude airplane since it must operate efficiently at all levels instead of at its design cruising level only, as is ordinarily the case with present day airplanes. The principal sources of difficulty from this requirement will be in the motor and cabin supercharging control which will probably require an independent supercharger unit, and in the propeller design. To operate at the maximum efficiency for such a range of altitudes and speeds, the propeller should have variable pitch, diameter, blade form, and number of blades, most of which features would be very difficult to design and construct.

The situation in regard to gusts at high altitudes is considerably more favorable. At this time differentiation between the meteorologist's and the aircraft designer's definitions of gusts should be made. The aircraft designer defines gusts as sudden changes of wind velocity relative to the plane, while the meteorologist defines gusts as changes of wind velocity relative to the mean wind velocity. Thus, the designer's definition allows a gust to be a steady condition. The principal source of gusts from the aircraft designer's standpoint lies in thunderstorms. In such phenomena the maximum vertical velocities are reached at altitudes of from 10,000 to 20,000 feet. Above these altitudes the vertical velocities will decrease, and above 25,000 feet they may, in general, be neglected. The design load factors for gust conditions for high altitude flight will, then, be unchanged from those for lower altitude operation, since these planes are already designed for the maximum gust conditions which will occur in the atmosphere.

Finally, consider the general weather conditions. At high altitudes, that is from 25,000 to 40,000 feet, the airplane will be above any weather conditions, aside from wind, which will influence its flight. However, it must still make an ascent and a descent, during which it may encounter the two most serious meteorological conditions for flight today, fog and icing. Thus the ship must be equipped in the same manner and have visibility as good as the low altitude airplanes.

In summary it may be said that flight at high altitudes offers certain definite advantages in speed and freedom from meteorological difficulties. However, these advantages can only be fully realized by increasing power. Furthermore, there are many problems, constructional and aerodynamic, which must be solved before safe flight can be accomplished at high altitudes. When these difficulties are overcome, nine to ten hour schedules from west to east will be attainable with high altitude equipment, but the east to west schedules will probably not be lowered to any great extent except by decreased power loadings, unless radical changes from conventional design are made.

Characteristics of Braked, Locked, and Free-Wheeling Two- and Three-Bladed Propellers

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(Received January 29, 1936)

Introduction

THE use of multi-engined aircraft has introduced the problem of aircraft performance when one or more power units have either become unusable or voluntarily shut down during cruising flight. If the use of the engine is to be discontinued because of mechanical failure, the desirable procedure is obviously to stop it altogether, so as to prevent possible destruction to the engine. This can be accomplished by locking the propeller, by a free-wheeling arrangement, or by feathering of a variable pitch propeller. If the use of the engine is to be discontinued merely to reduce fuel consumption, the propeller may be allowed to turn the engine, in which case the propeller is braked by a torque equal to the friction of the engine.

Another recent development connected with braked propellers is the fact that the variable pitch propeller now offers the possibility of using the large increment in drag at low blade angles of braked and free-wheeling propellers for reduction in landing speed or landing run of clean, highly powered, multi-engined aircraft.

It was the purpose of the present investigation to provide information not already made available by researches listed under the references at the end of this paper. Therefore the following discussion will be concerned chiefly with the three-bladed propeller and its effect on airplane characteristics, the two-bladed propeller being used principally for comparison purposes with other available data. The tests were performed at model scale, but their acceptance as applicable to full scale is supported by the favorable comparisons made in Reference 5.

The tests were made in the Guggenheim Aeronautics Laboratory, California Institute of Technology ten-foot wind tunnel, using a one-sixth scale model, the dimensions of which are shown in Fig. 1. The propeller was 18 inches in diameter. The blades were of aluminum alloy made to the specifications of the Hamilton Standard 1A1-0 blade. The blade could be adjusted to any pitch angle in a steel, split-type hub.

For a detailed description of the apparatus and method of determining the various parameters required in calculating the propeller coefficients and airplane characteristics, see References 2 and 5.

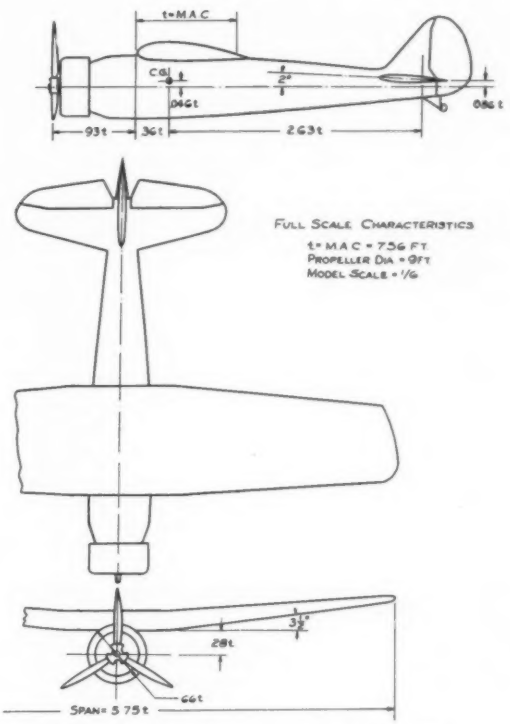

FIG. 1. Scale drawing of model used in tests.

Notation

The various coefficients used for presenting the data are defined as follows:

$J = V/nD$

$T_c = T/\rho V^2 D^2$

$Q_c = Q/\rho V^2 D^3$

$Q_n = Q_c\,(V/nD) = (17200\ Q_f/\text{propeller r.p.m.})/\sigma D^4 \times \text{m.p.h.}$

$Q_f =$ Friction torque (ft.lb.)

where

$T =$ Effective thrust (cf. Ref. 5). Negative sign indicates force in the direction of a drag force

$Q =$ Torque (ft.lb.). Negative sign indicates propeller turning engine

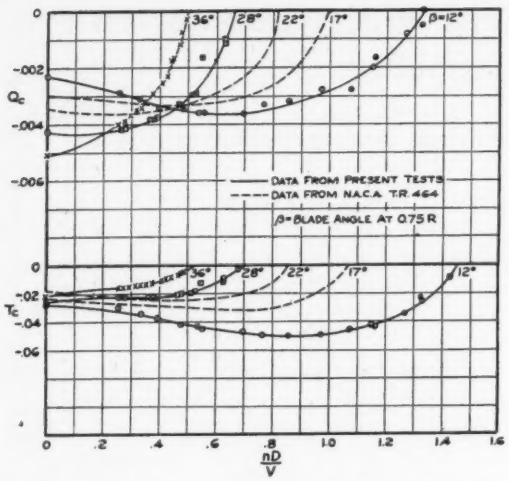

FIG. 2. Negative torque and thrust coefficients for two-bladed propeller.

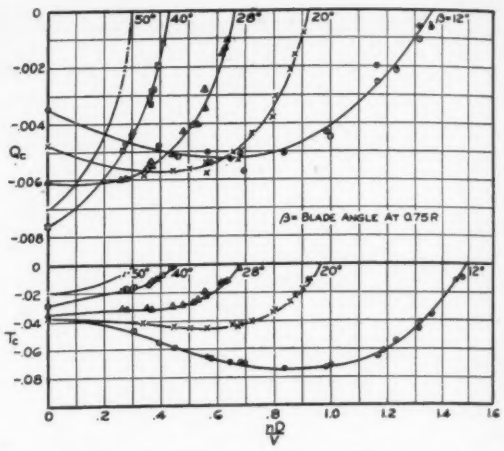

FIG. 3. Negative torque and thrust coefficients for three-bladed propeller.

V = Velocity (ft./sec.)
D = Propeller diameter (ft.)
β = Blade angle at 0.75 radius
h = Altitude (ft.)
ρ = Air density (slugs /cu.ft.)
σ = Relative density
n = Revolutions per second of propeller
N = Propeller r.p.m.
N_e = Engine crankshaft r.p.m.
Δ = Engine displacement (cu.in.)

For the presentation of airplane characteristics the usual coefficients C_L, C_D, C_M and α are used.

BRAKED PROPELLER

The condition of braking action of a propeller is obtained when the rate of advance has become so high that thrust and torque have both become negative. This condition can be brought about on existing single-engined aircraft during a fast glide and on multi-engined aircraft by reducing the revolutions of one engine below that of other units. If the propeller is allowed to turn a dead-engine, it will be braked by a torque equal to the friction torque of the engine at specified conditions.

To obtain data for the braked propeller curves, the model induction motor was used as an electrical brake by appropriate selection of supply power frequency. The first tests were performed with the two-bladed propeller for the purpose of obtaining a comparison with the data presented in N.A.C.A. T.R. 464 and of extending these data to higher blade angles. The results are shown in Fig. 2. As the model configuration used for these tests differed largely from that of a monoplane wing with nacelle in position *C* (loc. cit.), the comparison should be regarded as merely qualitative. The extension to higher blade angles shows that the negative torque curves become much steeper, reaching greater negative torques, and that the negative thrust curves become less steep with corresponding decrease in negative thrust.

In Fig. 3 are presented the characteristics of the three-bladed propeller for blade angles varying from 12° to 50°. The curves very closely resemble those of the two-bladed propeller, differing primarily in the greater values of negative torque and thrust reached for a given blade angle.

For both the two- and three-bladed propellers the region between nD/V equal to 0 and 0.25 could not be covered because of the excessively low rotational speeds or excessively high wind tunnel velocities required. The points for nD/V equal to 0 were obtained from locked propeller data.

The determination from the above curves of the negative torque and thrust for a propeller restrained to a predetermined r.p.m. by regulation of engine power requires only a knowledge of the forward velocity, propeller diameter, and blade angle. The determination of the negative thrust caused by a propeller overcoming the friction torque of a dead-engine requires in addition information with regard to the friction characteristics of the engine.

Through the cooperation of the Army, Navy, and several engine manufacturers, the authors were able to collect friction horsepower curves for a considerable number of radial engines ranging from 150 to nearly 1000 hp. In Fig. 4 these friction horsepower curves have been replotted against r.p.m.

Flight tests indicate that the rotational speeds of all normal propellers turning a dead-engine on a multi-engine airplane range from 35 per cent to 50 per cent of rated r.p.m. (Ref. 3). To obtain the friction horsepower in this range it was necessary to extrapolate many of the curves of Fig. 4 towards the origin. The accuracy of such an extrapolation naturally depends very largely on individual judgment, and its validity, therefore, cannot be definitely determined until more engine test data become available.

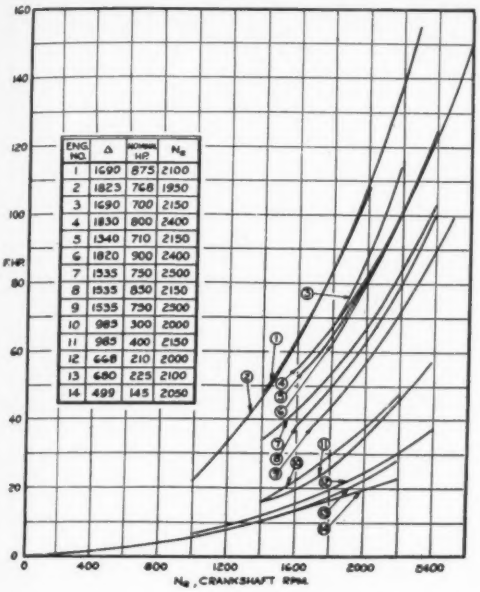

FIG. 4. Friction horsepower of various radial, aircraft engines.

Investigations made on the friction horsepower of aircraft engines reveal that in general:

(1) F.hp. increases with r.p.m.
(2) F.hp. increases with displacement.
(3) F.hp. increases with compression ratio (questionable).
(4) F.hp. decreases with throttle opening.
(5) F.hp. decreases with increasing temperature.
(6) F.hp. depends greatly on viscosity of oil used.
(7) F.hp. depends greatly on mechanical conditions of engine.

For an engine of given design the friction horsepower of a dead-engine will depend principally on the r.p.m. and the oil temperature. The temperature in turn is dependent on the altitude at which the aircraft is flying.

The points shown in Fig. 5 were obtained by taking the average slope of the Q_f *vs.* engine r.p.m. curves determined from Fig. 4 for the range of r.p.m. from 35 per cent to 50 per cent of the rated r.p.m. For the curve faired through these points, an empirical formula was developed which should give an indication of the friction torque to be encountered in dead-engines of various displacements. A correction for altitude has also been included. The data for this were obtained from engine tests on a Wright R-1820-F-2 engine covering the range of altitudes shown in Fig. 7. The formula is of the form:

$$Q_f/N_e = \Delta\ (0.3\Delta + 0.0143h - 6)\ 10^{-7}$$

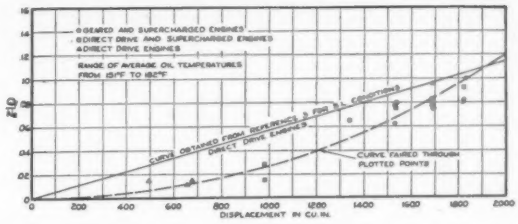
GEARED AND SUPERCHARGED ENGINES
DIRECT DRIVE AND SUPERCHARGED ENGINES
DIRECT DRIVE ENGINES
RANGE OF AVERAGE OIL TEMPERATURES FROM 151°F TO 182°F
CURVE OBTAINED FROM REFERENCES 2 AND 3, S.L. CONDITIONS
DIRECT DRIVE ENGINES
CURVE FAIRED THROUGH PLOTTED POINTS
Q_f/N_e
DISPLACEMENT IN CU. IN.

FIG. 5. Variation of Q_f/N_e ratio with displacement showing proposed empirical curves.

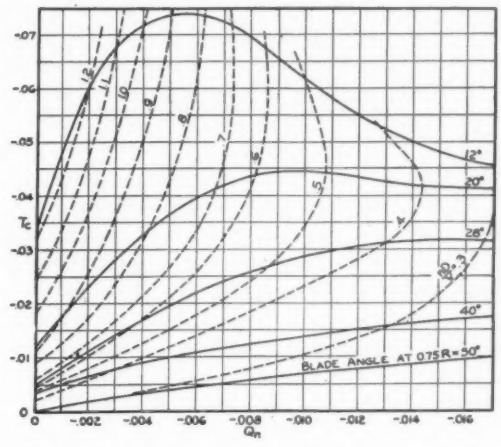

FIG. 6. Negative thrust and torque-r.p.m. coefficients for three-bladed propeller.

In the ratio Q_f/N_e, N_e refers to the r.p.m. of the engine crankshaft. After obtaining Q_f/N from an engine curve or from the above equation, the following method taken from Reference 3 can be used to determine negative thrust:

Estimate flight velocity.

Calculate Q_n *or* Q_c. Calculation of Q_c requires an assumption for n.

For three-bladed propellers obtain T_c from Fig. 6 which has been obtained from Fig. 3 by cross-plotting. For two-bladed propellers use the data of Fig. 2 or the cross-plot given in Reference 3. If Q_c has been determined, Fig. 2 or Fig. 3 is more convenient.

Since Q_f/N_e was assumed constant over the range to be considered, there is no need to correct the n obtained from nD/V in Fig. 6. If, however, n was assumed to obtain Q_f and hence Q_c, it is necessary to check the assumption.

Fig. 5 shows a curve corresponding to the equation for Q_f/N_e given in Reference 3. Since it falls higher than the points, which were calculated from experimental friction data, it appears conservative for three-bladed propellers for blade angles of 28° and greater, while it may be the opposite for blade angles below 28° due to the peak in the curves below 28° (See Fig. 6) and the possibility of falling on the right hand side of the peak with high values of Q_n.

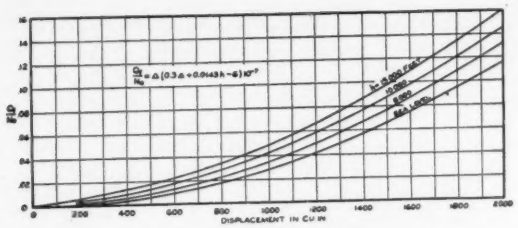

FIG. 7. Variation of Q_f/N_e with altitude.

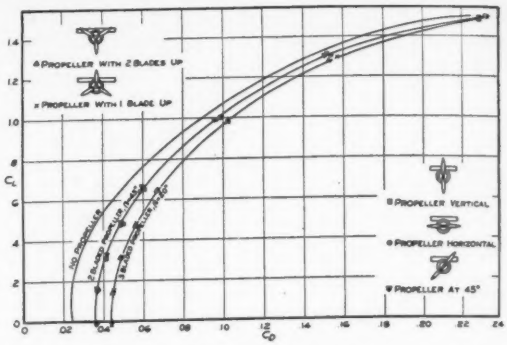

FIG. 8. Effect of locked propeller position on airplane polars.

LOCKED PROPELLER

The second group of tests was made to find the change in airplane characteristics caused by a propeller locked in various positions. In these tests the propeller hub was rigidly locked to the face plate of the motor stator so the torque developed by the blades could be measured. The two-bladed propeller was locked in three different positions: blades vertical, horizontal, and at 45°. The three-bladed propeller was locked in two positions: one blade vertically down and one blade vertically up. In the first tests three component measurements were made at the various propeller positions for a given blade angle, and the intention was to make tests for all of the permutations if necessary. However, the polars plotted in Fig. 8 showed such negligible differences for the various positions that it was thought unnecessary to carry out all of the proposed tests. Instead, that position was selected which should cause the greatest disturbance in the flow over the wing. For the two-bladed propeller the horizontal position was selected, for the three-bladed propeller the position with one blade vertically down.

At these positions the range of blade angles between 0° and 90° was traversed. The complete results are plotted in Fig. 9 from which it is apparent that the negative thrust of a locked propeller for both two and three blades increases with reduction in blade angle, reaching a maximum at about 10°. The curve for three blades is

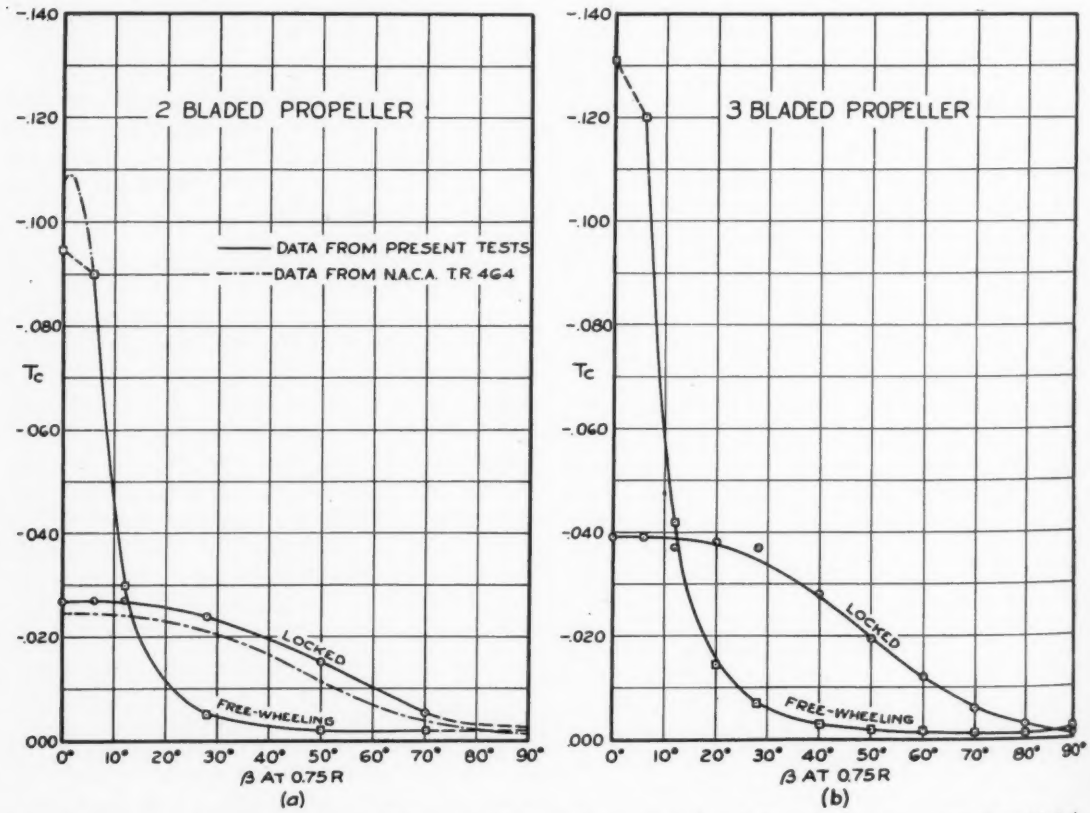

FIG. 9. Variation of negative thrust coefficient with blade angle for locked and free-wheeling two- and three-bladed propellers.

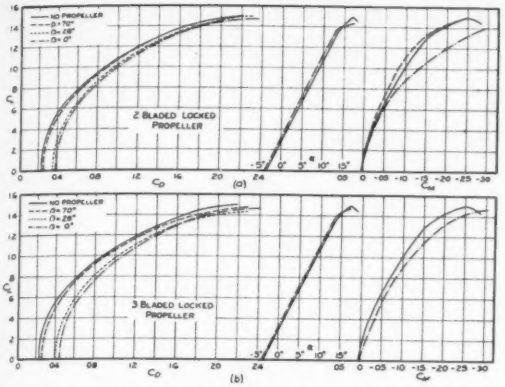

FIG. 10. Effect of locked two- and three-bladed propellers on three component airplane data.

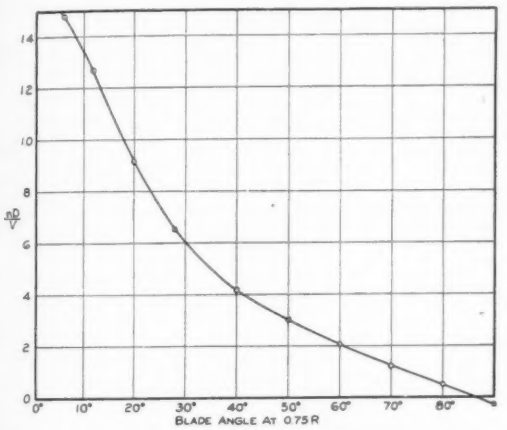

FIG. 11. Variation of nD/V ratio with blade angle for free-wheeling two- and three-bladed propellers.

similar to that for two blades, differing primarily in the higher negative thrusts reached. In Fig. 9(a) comparison is made with data presented in Reference 1. The lower values of negative thrust given by the latter for the locked propeller can be accounted for by the difference in blade sections and in the solidity ratio of the propeller tested.

Fig. 10 shows the effect of locked propeller on the airplane three component data. For both two- and three-bladed propeller configurations the drag polar remains the same in shape, moving as a whole in the direction of greater drag as the blade angle decreases. The C_L *vs.* α curve remains the same in slope, moving slightly to the left with decrease in blade angle. The C_M *vs.* C_L curves for the two-bladed propeller for blade angles below about 50° show a stabilizing effect due to the propeller. Above 50° a destabilizing effect is apparent. The three-bladed propeller furnishes similar results (Fig. 10-b) except that the propeller has a stabilizing effect at all blade angles. The curves of C_L *vs.* α and C_L *vs.* C_M plotted show the extreme limits reached by any blade setting.

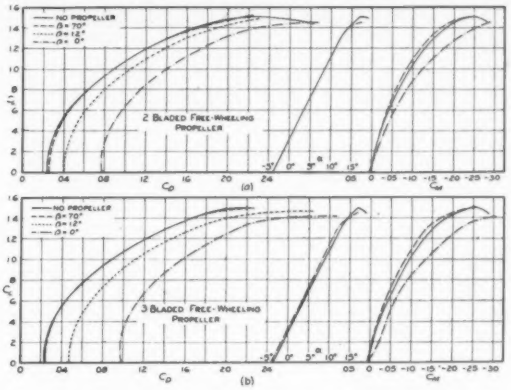

FIG. 12. Effect of free-wheeling two- and three-bladed propellers on three component airplane data.

FREE-WHEELING PROPELLER

For the free-wheeling propeller tests, the propeller hub was keyed to the rotor of the motor so that the propeller supplied sufficient torque to overcome the friction of the rotor bearings and counter gears, and the windage loss of the blower. This torque was so small as not to be measurable by the torque meter. Because of the high rotational speeds at low blade angles the wind tunnel velocity was reduced at these angles. The order of magnitude of the r.p.m. reached by the free-wheeling propeller for any tunnel speed, V, can be calculated from the curve shown in Fig. 11. The curves for the two- and three-bladed propellers coincide.

The free-wheeling propeller adds to the drag of the airplane principally by offering additional parasite area and by disturbing the flow over the wing. In the tests the propeller was mounted at a considerable distance from the leading edge of the wing as shown in Fig. 1. For propellers mounted much closer to the wing, as on current multi-engined aircraft, a different effect might be expected.

Fig. 9 shows that for free-wheeling two- and three-bladed propellers, an angle of 30° would be large enough to give practically the minimum deleterious effect on airplane performance. Little advantage would be gained by going to blade angles in excess of 50°. From the three component data plotted in Fig. 12, it is found that the free-wheeling propeller produces similar effects to those mentioned for the locked propeller in Fig. 10, except that unstable tendencies occur at and above about 10° for the two-bladed propeller and about 50° for the three-bladed propeller.

CONCLUSIONS

1. The negative torque and thrust characteristics of a three-bladed propeller are similar to those of a two-bladed propeller, differing in the larger negative maxima reached.

TABLE I

NEGATIVE THRUST COEFFICIENT FOR VARIOUS PROPELLER CONDITIONS

Blade Angle		Two-Bladed Propeller				Three-Bladed Propeller			
		12°	20°	28°	40°	12°	20°	28°	40°
Braked Propeller	$\frac{nD}{V}=.6$	−.045	−.028	−.012	+	−.067	−.044	−.017	+
	$\frac{nD}{V}=.82$	−.050	−.020	+	+	−.074	−.032	+	+
	$\frac{nD}{V}=.95$	−.050	−.000	+	+	−.073	−.006	+	+
Locked Propeller		−.027	−.026	−.024	−.019	−.039	−.038	−.035	−.028
F.-W. Propeller		−.032	−.012	−.006	−.003	−.040	−.016	−.008	−.003

Note: + Indicates positive thrust coefficient.

2. The braking force supplied by a dead-engine can be calculated by the method indicated in this paper. The formula given should closely approximate actual conditions in view of the considerable amount of friction horsepower data upon which it is based.

3. The position of the locked propeller has little effect on airplane characteristics.

4. The negative thrust of a free-wheeling propeller at blade angles above 12° is less than that for a locked propeller.

5. The locked and free-wheeling propeller for high wing monoplanes similar to that tested, produces a shift of the drag polar in the direction of increasing drag, has little effect on the lift and causes a destabilizing effect which is greater with the two-bladed than with the three-bladed propeller.

6. In Table 1 the negative thrust coefficient, T_c, for different propeller conditions has been tabulated. The values for the angles calculated show that the greatest increase in drag will be obtained from the braked propeller and the minimum increase from the free-wheeling propeller properly set.

The authors wish to thank Dr. Clark B. Millikan for his direction of the research, the members of the staff of the Guggenheim Aeronautics Laboratory at the California Institute of Technology for assistance in carrying out this investigation, and the Army, Navy, and various engine manufacturing companies for their generous co-operation in supplying friction horsepower data.

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On the Common Space Integrals of Aerodynamics

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(Received August 26, 1935)

Total Kinetic Energy

THE inability of the human intellect to comprehend more than one numerical value at the same time, and more than a few within a given time, recommends the total kinetic energy of an aerodynamic fluid motion as that individual numerical value which gives by itself the richest instruction regarding the flow. This total energy K is computed in full analogy to the procedure with solid motion. Let dS denote the volume of the space elements filled with the fluid, and let ρ denote the density of the fluid, so that ρdS would be the mass of the fluid elements. Let v, a vector, denote the velocity of the fluid particle, so that—$v{\cdot}v$, the dot product of the velocity by its anti-vector, is equal to the (positive) square of the magnitude of the velocity. Then, in accordance with general dynamics, the kinetic energy of each fluid particle is

$$dK = -dS\, v{\cdot}v\, (\rho/2) \tag{1}$$

and hence the total kinetic energy of the fluid is

$$K = -\int \tfrac{1}{2}\, \rho\, dS\, v{\cdot}v \tag{2}$$

where the space integration extends through the entire fluid.

Since the fluid motions of aerodynamics are created by finite forces acting through finite distances, the above integral (2) must be finite. Indeed, in these cases, the integrant, at large distances from the object giving rise to the flow, decreases in proportion to the sixth power of the distance. Integral (2) is therefore convergent. It always gives the same value regardless of the order in which the contributions of the several fluid particles are considered, or, in other words, regardless of the manner in which a very large space is finally considered the equivalent of the "infinite" space. The kinetic energy is effectively concentrated in the vicinity of the solid.

Velocity Potential

The actual evaluation of space integral (2) in any particular case in which the velocity distribution v is given, involves in some form three steps because our space has three dimensions. The space integral has to be reduced to a surface integral, as the first step, by a first integration. A second integration reduces the surface integral to a line integral. This line integral has, finally, to be solved by a third integration. The details of these three steps, though they have to be in harmony with the particular problem, still, to a considerable extent, are left to the choice of the computer

If the motion of the perfect fluid was entirely caused by the motion of a solid immersed therein, the velocity distribution v possesses a potential P of which it is the antigradient:

$$\mathrm{v} = \nabla P \tag{3}$$

That is to say, there does then exist a quantity P from which the velocity v may be obtained by the execution of the differentiation process ∇. Conversely, P can be considered as the outcome of one integration step applied to v. It therefore suggests itself to inquire whether the first integration step in the evaluation of the integral (2) may not be obviated, or replaced, by the introduction of the potential P, since this quantity implicitly carries one integration step in it, although not the particular integration demanded in Eq. (2). This can now be and is generally done, and the mathematical nature of the transformation in question may be discussed.

Vector Differentiation

Vector differentiation means three-dimensional differentiation. The operation ∇, it must be understood, defines in substance a surface value per volume. The volume is that of a diminutive space element considered to be of small extension in all directions. The surface in question surrounds this space element. This operation ∇ is unitary, and a very basic property of space is therein revealed. The statement that the surface value mentioned is in form an integral but in substance a differential should not be confusing. It is the sum of all small surface elements do of the surface o surrounding the space element dS, each multiplied by the quantity to be differentiated. Such a sum is formally an integral, but an infinitely small one in this case. The surface elements do are vectors, and those facing each other are opposite in direction, the positive direction being always taken towards the inside of the space element. Hence the formal addition amounts to a subtraction, and the integration turns into the formation of a differential. This sum is finally divided by the volume of the space element, making the differentiation complete.

∇P, for instance, describes the following sequence of steps. Select a small space element dS bounded by all surface elements do. Each element do is a vector directed to the inside. Multiply each by its value of P. Add all products (vectors) so obtained. Divide the final sum by the volume of the space element dS. The result is a finite vector in general, the antigradient of P, and always the same one at each point, whatever the shape of the space element.

If P is a pressure distribution, ∇P is the buoyancy per unit volume at each point, exerted by the fluid on its particles.

Gauss' Theorem

The procedure applied to an infinitely small space element for obtaining the differential involved in the operation ∇ can also be applied to the closed surface of a finite region of space. The result is then a genuine surface integral. As such, it stands in a very simple relation to the equivalent surface values per volume of the enclosed space. If the operation ∇ is applied in succession to two adjacent space elements, and multiplied by the volumes dS (that is reduced again to the differential) and the differentials obtained are added, the common boundary between the two elements does not contribute to the result, each element do being positive with respect to one space element but negative with respect to the other; for the two inside directions are opposite. Repeating this addition many times, with respect to all space elements into which the space region may be divided, leaves, finally, the surface elements of the space region as the only ones contributing to the result. Thus, for instance

$$\int do\, P = \int dS\, \nabla P \tag{4}$$

The surface integral of the potential is equal to the space integral of its antigradient. By way of a skeleton equation, we can write more generally

$$do = dS\, \nabla \tag{5}$$

which gives a correct equation, (but is none in itself) by introducing the integral signs and the quantity to be multiplied, together with the multiplication symbol to be employed, if any.

The generalized Gauss' theorem, Eqs. (4) and (5) transforms an integral over a closed surface into an integral through the enclosed space by the application of a differentiation process, namely of the operation ∇ . In actual work, and also in that which follows, the opposite transformation occurs as often, namely the transformation of a space integral into an integral over the enclosed surface. This constitutes integration. A function has to be determined which when subjected to the operation ∇ gives the originally given space integrant.

A symbol reversing ∇ would enable us to describe such mathematical discussion in a straight, forward, direct, and positive manner. Without such symbol, there remains only the alternative of interrupting the logical exposition, to start out with newly introducing some suitable expression, to differentiate the same by ∇, and to verify in that way that a formerly given expression results then. After that, Eq. (5) is applied in reversed order.

The latter and less perfect method, as is generally done, will be followed in this paper. It should be remembered, however, that there exists a vector integration operator, analogous to ∇ and reversing it, which obeys all laws of vector analysis, besides being restricted by limitations natural to an integration symbol. The circuitous way chosen is not unavoidable.

Reduction of Space Integral Into Surface Integral

These explanations open the way for the reduction of the space integral of Eq. (2) into a surface integral by means of introducing the potential P of Eq. (3). Consider now only the essential portion

$$\int dS\; v \cdot v \tag{6}$$

of Eq. (2). Substituting in Eq. (3), we obtain

$$\int dS\, v \cdot v = \int dS \nabla P \cdot v \tag{7}$$

Here, the combination $dS\, \nabla$ offers itself to the eye, and we are tempted to apply the skeleton Eq. (5) to it. We must not do so, however, because ∇ in Eq. (7) is only directly multiplied by P but not by by v. Only a portion of the expression in Eq. (7) appears differentiated. Eq. (5) requires that everything behind ∇ be directly and unconditionally multiplied or associated with it, so that the differentiation extend to all factors. As the next step, it is necessary to obtain an expression where that takes place, such that Eq. (7) appears as a constituent thereof. In other words, integration by parts will have to be employed. Eq. (7) contains the expression

$$\nabla P \cdot v \tag{8}$$

in which only P is differentiated, because it alone is directly associated with ∇. Compare with that

$$\nabla \cdot P\, v \tag{9}$$

Considered purely vector analytically, that is geometrically, as if ∇ were a real vector, Eqs. (8) and (9) would be equal. In Eq. (9), however, both factors P and v, after first being multiplied by each other, are then combined in unison with ∇. Both factors are therefore differentiated. In Eq. (8), P only is differentiated, being multiplied by ∇, and the result is multiplied by v. In Eq. (9), but not in Eq. (8), the derivative is the outcome of a differentiation process executed on a product of two factors. As in ordinary calculus, it can be expressed as the sum of two derivatives, (a doubling up), in each of which only one factor

appears differentiated. Both terms, individually, must each agree (by itself) with the original term considered, namely from the purely geometrical or vector analytical aspect, (if ∇ were an ordinary vector). They disagree only with respect to how far the differentiation extends.

In the present case, we obtain

$$\nabla \cdot Pv = \nabla P \cdot v + P \nabla \cdot v \tag{10}$$

This equation complies with all conditions stated, and the second term is the one contained in Eq. (7). Integrating Eq. (10)

$$\int dS \nabla \cdot Pv = \int dS \nabla P \cdot v + \int dS P \nabla \cdot v \tag{11}$$

or, otherwise arranged

$$\int dS \nabla P \cdot v = \int dS \nabla \cdot Pv - \int dS P \nabla \cdot v \tag{12}$$

and applying at last Eq. (5) to the second term

$$\int dS \nabla P \cdot v = \int do \cdot Pv - \int dS P \nabla \cdot v \tag{13}$$

which is the desired transformation.

The original space integral has thus been transformed, not into a surface integral indeed, but into the difference between a surface integral and another space integral.

Under the physical conditions of the present problem, that other space integral, in actual flows of an incompressible fluid, becomes zero, because $\nabla \cdot v$, the divergence, or source intensity per unit volume, must be zero. Under that additional condition, then, the reduction becomes complete

$$\int dS\, v \cdot v = \int dS\, v \cdot \nabla P = \int do \cdot vP \tag{14}$$

Merely fictitious motions of a perfect fluid, as they will occur in theory, generally have divergence, however, and then the third term of Eq. (13) does not vanish. Eq. (14) constitutes the usual and classical way how to compute the kinetic energy of a potential flow of a perfect fluid. The flux increments $do \cdot v$ over the surface have to be added up after having been multiplied by the potential. (Compare Lamb, *Hydrodynamics,* 5th ed., p. 44, Eq. (4)).

Transformation of the Surface Integral Into Another One

In what follows now, the analysis takes cognizance of the further limitation that the fluid motion is caused by the translational motion of a solid with velocity u. The flux occurring in Eq. (14) can then also be obtained from u

$$do \cdot v = do \cdot u \tag{15}$$

This is exactly the boundary condition, expressing the thought that the cavity created by the translation of each surface element is immediately filled up by the moving fluid.

The substitution of Eq. (15) into Eq. (14) gives

$$\int dS\, v \cdot v = \int do \cdot u P \tag{16}$$

Now, however, u is a constant vector, not variable, as v. u can therefore be placed in front of the integral

$$\int dS\, v \cdot v = u \cdot \int do\, P \tag{17}$$

There has thus arrived the surface integral of the potential, $\int do\, P$.

Transformation of the New Surface Integral Into a Space Integral

This new surface integral is transformed, by Eq. (4), into a space integral

$$\int dS\, v \cdot v = u \cdot \int do\, P = u \cdot \int dS\, v \tag{18}$$

Substituting Eq. (18) in Eq (2) gives

$$K = -\tfrac{1}{2} \rho \int dS\, v \cdot v = -\tfrac{1}{2} P u \cdot \int dS\, v \tag{19}$$

The volume integral of the velocity, multiplied by the density, is naturally interpreted as the momentum of the fluid, namely as its principal value, by which limitation "principal value" it shall be expressed that this momentum can be computed by evaluating the surface integral of the potential (multiplying the same in addition by the density) over the surface of the solid only. This express limitation flows from the method of arriving at the integral. Without this limitation, the volume integral of the velocity would be indeterminable, since it would depend on the order in which the space elements are considered. The momentum is not concentrated around the solid, and its space integral fails to converge. The limitation means, physically, that the entire momentum transmitted through the surface of the solid is considered, whether still contained in the fluid, or transmitted to some portion of the total dynamic system considered outside the fluid.

Fictitious Inside Flow

The space integral of the velocity in Eq. (19) represents furthermore the actual momentum of any fictitious flow inside the surface of the solid. With that, the question of an integration through an infinite space does not come in. If this fictitious flow possesses a potential Q, equal to P at all points of the surface of the solid, this space integral can be used for the computation of the total energy in the last term of Eq. (19).

It should be noted that the fictitious inside flow is generally not free of divergence or of a source and sink system. It is only stipulated that it possesses a potential agreeing with P at the surface. This potential is not subjected to any limitation, such as Laplace's equation expressing that the divergence of the velocity is

zero. It follows that neither the fictitious inside flow, nor its potential, is uniquely determined, but on the contrary there exist a great many of such flows having the potential P at the surface.

Transformation of the New Space Integral

The momentum integrals

$$\int do\, Q = \int dS\, v \tag{4a}$$

are finally transformed into the sum of another space integral and of a surface integral which is more convenient in certain cases. That transformation flows from the relation

$$\nabla \cdot v\,;r = \nabla \cdot v\ r + v \cdot \nabla\,;r \tag{20}$$

in which r denotes the radius vector, that is the vector connecting an origin with the point in question, serving thus as its vector coordinate.

The symbol ";" denotes dyadic multiplication, in which only the magnitudes of the two vectors multiplied with each other merge into the product of their magnitudes, but the individual directions of the two vectors remain preserved. A further merging of these directions takes place by addition of dyadics, according to

$$a;b + a;c = a;(b+c) \tag{21}$$

Such a sum of any number of dyadic products of a pair of vectors represents the geometric characteristics of stresses, deformations, and the like.

The left hand side of Eq. (20) contains a product of two factors which in its entirety is multiplied by ∇, and hence both factors appear differentiated. It is doubled up on the right hand side, so that in each of the two terms only one factor, that directly associated with ∇, is differentiated. From the purely geometrical, or vector analytical point of view, that is if an ordinary vector would be substituted for ∇, either of the two right hand expressions in Eq. (20) is equal to the left hand side. That is to say

$$a \cdot b;c = a \cdot b\, c, \text{ by definition of ";"} \tag{22}$$

and

$$a \cdot b\ c = b \cdot a\ c \tag{23}$$

because $a \cdot b = b \cdot a$, by the most elementary rule of vector analysis.

Furthermore, $\nabla;r$ is equal to the identity dyadic, so that its dot product by any vector is equal to that vector itself. This follows from the fact that always $\nabla;w$ is the "derivation" of any vector field w, meaning that

$$dw = dr \cdot \nabla;w \tag{24}$$

so that if w is the radius vector itself

$$dr = dr \cdot \nabla;r \tag{25}$$

which, as it holds for any value or dr proves that $\nabla;r$ is the unit dyadic.

It follows that Eq. (20) can also be written

$$\nabla \cdot v;r = \nabla \cdot vr - v \tag{26}$$

or

$$v = \nabla \cdot v\, r - \nabla \cdot v\, r \tag{27}$$

Integrating:

$$\int dS\, v = \int do \cdot vr - \int dS\, \nabla \cdot v\, r \tag{28}$$

In executing the last step Eq. (4) has been applied to the middle term.

In other words, the momentum of a body of fluid of constant density is equal to the static moment of its divergence (source system) and of the inflow or negative flux through its surface.

It is remarkable that this momentum theorem holds for all continuous motions conceivable. The existence of a potential was not assumed.

If the limitation underlying Eq. (15) is introduced, then by this equation, the surface integral term of Eq. (28) becomes equal to the product of u and the volume of the solid.

Apparent Additional Mass

Having thus obtained three methods for the computation of the kinetic energy of the fluid surrounding the translating solid, one is now prepared to compute the so-called additional apparent mass or its volume or coefficient in three analogous ways. The kinetic energy has to be divided by the dynamic pressure; the momentum (in case of symmetry, otherwise its component parallel to the motion), has to be divided by the product of velocity u times density.

Two of the methods, differing only in the way of computing the flux through the surface elements, are closely related. The procedure is however different, whether the flux is computed from the constant velocity of translation u or from the variable velocity distribution v.

It appears in this connection that the relation between the velocity of translation u and the momentum of the flow is not really expressed by a scalar apparent additional mass, but by an individual dyadic Σ such that

$$m = u \cdot \Sigma$$

the momentum being in general not parallel to the velocity. The apparent mass is different in general in different orientation of the solid. Strictly speaking, there exists an apparent additional mass for the momentum component in direction of motion and another for the momentum component at right angles thereto. The analogy to a stress, as far as the geometric aspect is concerned, is clearly apparent.

Rankine Body

By way of illustration, apply the different methods of computing the inertia factor to the special case of a Rankine body of infinitely large elongation.

Let the points in a plane be determined by the system of ordinary polar coordinates r and ϕ, let $y = r \sin \phi$, $x = r \cos \phi$, and let s denote $\sin \phi/2$. Consider the surface of revolution about the x axis as the axis with the meridian curve

$$r = 1/s \tag{29}$$

$$y = r \sin \phi = 2(1 - s^2)^{\frac{1}{2}} \tag{30}$$

The crossection of the surface has then the magnitude

$$A = y^2 \pi = 4\pi(1 - s^2) \tag{31}$$

The crossection at infinity is accordingly

$$A_\infty = 4\pi \tag{32}$$

The crossection of the shell between the surface and the cylinder enveloping it in infinity is

$$A_\infty - A = 4\pi s^2 \tag{33}$$

The volume of the largest sphere fitting in the surface (at infinity)

$$Vol_s = 32\pi/3 \tag{34}$$

Furthermore, we have

$$dA/ds = -8\pi s \tag{35}$$

The flux of the parallel flow with constant velocity equal to ONE parallel to the x axis is equal to the values of A, the maximum being 4π.

The solid angle of a crossection A seen from the origin is equal to $1 - s^2$.

The source distribution corresponding to this shape is accordingly a point source with delivery 4π, located at the origin. For such source, the rate of change of flux through the surface per change of s is $-8\pi s$.

The volume of the surrounding cylinder from a far point $x = L$ up to the nose of the surface $x = -1$ is equal to $(L + 1)\, 4\pi$. The volume of the shell between said cylinder and the surface is

$$\int_0^1 4\pi s^2 (1/s^2 + 2)\, ds = 20/3\, \pi \tag{36}$$

Hence the volume of the surface enclosed Rankine body is $4\pi L - 8/3\pi$.

The source moment is equal to $4\pi L$.

The surface integral of flux times potential is

$$\int_0^1 (8/3)\, s^2 ds \int_0^1 (8/3)\, s^2 ds = 8/3\, \pi. \tag{37}$$

the potential of the point source being equal to $4\pi/r = 4\pi s$. The difference between the source moment and the volume is likewise equal to $8/3\pi$.

It appears in either case that the volume of apparent additional mass of an infinitely elongated Rankine body is equal to one-fourth of the volume of the largest inscribed sphere, one-fourth for each end.

That the volume of the solid plus the volume of apparent additional mass is always equal to the static moment of the source system divided by the velocity is also verified for the case of an ellipsoid; see Lamb, *Hydrodynamics,* 5th ed., page 144.

The Torsional Strength of Solid and Hollow Cylindrical Sections of Heat-Treated Alloy Steel

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(Received November 20, 1935)

Summary

THE author noted from a few exploratory tests in a study of the torsion characteristics of heat-treated chromium-molybdenum steel (X4130) cylindrical tubing of constant length/diameter ratio that there was an appreciable effect due to variations in this factor, especially for tubing with high tensile properties. Consequently the study was expanded and the results obtained are presented in the form of an empirical equation and charts as aids to the designer who is concerned with the torsional strength of heat-treated alloy steel tubing and solid sections.

Formula and Design Application

The critical torsional shearing stress S_t, also known as the Modulus of Rupture, is determined by the following empirical equation:

$$S_t = KF/(L/D)^{1/10} \qquad (1)$$

where S_t = torsional stress in lbs. per sq. in.
K = ultimate tensile stress in lbs. per sq. in.
L = length of member in inches.
D = diameter of member in inches.
t = wall-thickness of member in inches.
F = a value for the ratio of diameter in inches/wall thickness in inches obtained from the curve in Fig. 1, or from the following approximate formula for the curve:

$$(D/t)/[-0.330 + 1.048D/t + 0.01276\ (D/t)^2]$$

Eq. (1) was derived from actual test data obtained on cylindrical sections with length/diameter ratios from 1.5 to 25 and diameter/wall-thickness ratios from 2 to 75, and ranging in ultimate tensile strengths from 110,000 to 200,000 lbs. per square inch.

A family of curves for the determination of the torsional strength of cylindrical solid and tubular sections, formulated from Eq. (1) are given in Fig. 2 and include only the range of factors studied. The ratios of length/diameter from 1.5 to 25 are given as abscissae and those for diameter/wall-thickness are shown as a series of solid lines designated from 2 to 75. The stresses for the Modulus of Rupture are given along the vertical scale for material of 100,000 lbs. per square inch tensile strength.

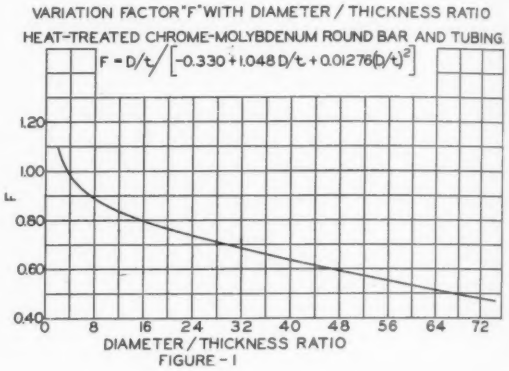

FIGURE - 1

A cylindrical section with a ratio of length/diameter of 12 and with a ratio of diameter to wall-thickness of 10 would develop torsional stresses of 68,000, 85,000, 102,000, 122,000 and 136,000 lbs. per square inch for respective tensile strengths of 100,000, 125,000, 150,000, 180,000 and 200,000 lbs. per square inch The vertical torsional stress scale at the left of Fig. 2 for the tensile stress of 100,000 lbs. per square inch is read from the horizontal line passing through the point of intersection of the vertical line for the L/D ratio (length/diameter ratio) and the curved solid line for the D/t ratio (diameter to wall-thickness ratio). For any desired tensile strength the corresponding torsional stress may be computed by determining the stress from Fig. 2 for a tensile strength of 100,000 lbs. per square inch and multiplying this value by the ratio of the desired tensile stress to 100,000. As an example, the torsional strength for the tubing previously cited is 68,000 based on a tube with a tensile strength of 100,000 lbs. per square inch. The same tubing heat-treated to a tensile strength of 160,000 would develop a torsional strength of 68,000 (160,000/100,000), or 108,800 lbs. per square inch.

With reference to Eq. (1) it will be noted that the torsional stress is equal to the tensile stress divided by $(L/D)^{1/10}$ ratio times the factor F for the D/t ratio, The factor F is determined directly from Fig. 1 or by the formula noted thereon. It is obtained from the intersection of the vertical line for the desired D/t ratio and the curved line projected to the left along the horizontal line. For example, for a D/t ratio of 40 the factor to be used for F in the equation is 0.64.

TORSIONAL STRENGTH OF ROUND BAR AND TUBULAR STOCK
CHROME-MOLYBDENUM HEAT TREATED MATERIAL ONLY (QUENCHED & DRAWN)

FOR ANY OTHER ULTIMATE TENSILE STRESS MODULUS OF RUPTURE
EQUALS MODULUS OF RUPTURE FOR 100 000 PSI TENSILE
MULTIPLIED BY RATIO $\frac{\text{ACTUAL ULTIMATE TENSILE STRESS}}{100\,000}$
MAXIMUM ALLOWABLE TORSIONAL STRESS SHALL NOT EXCEED ULTIMATE TENSILE STRESS

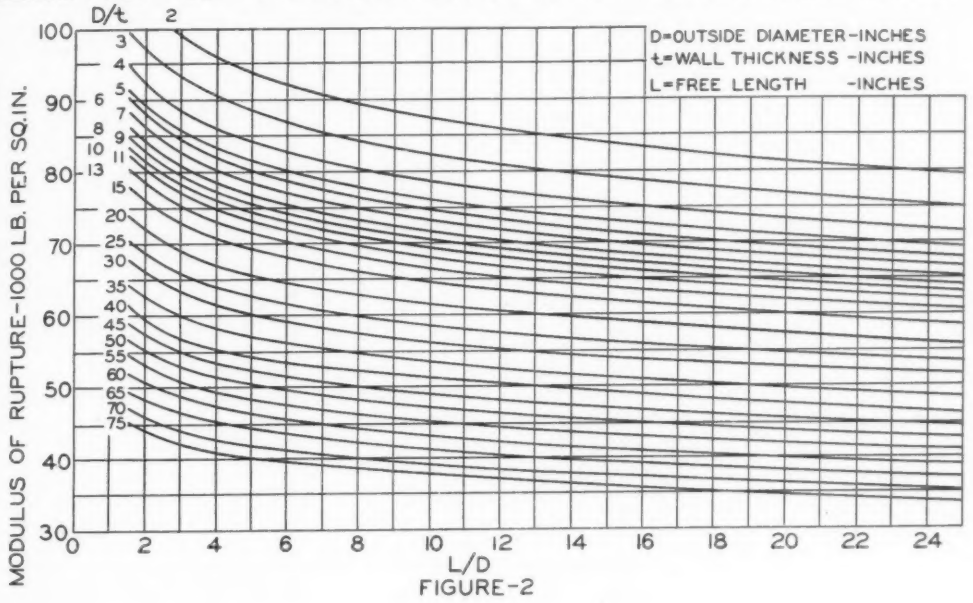

FIGURE-2

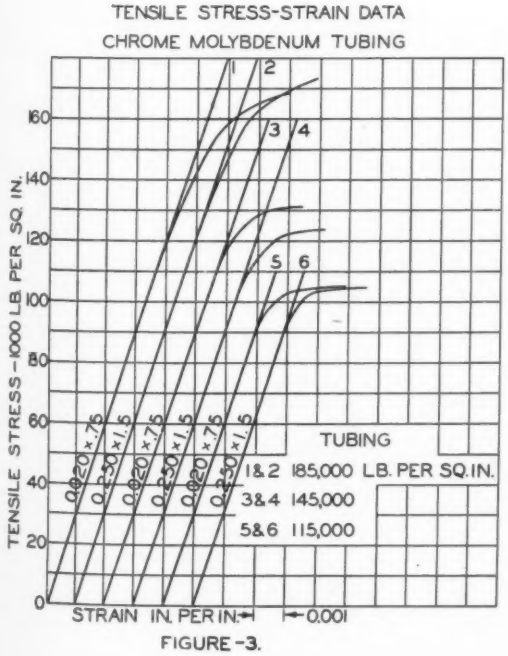

FIGURE-3.

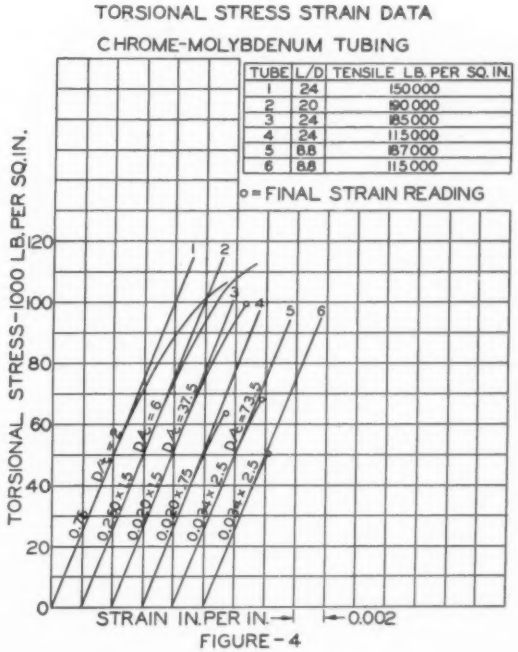

FIGURE-4

TABLE I

TENSILE PROPERTIES OF HEAT-TREATED CHROME-MOLYBDENUM ROUND BAR AND TUBULAR STOCK

Dimensions, inches	Yield—Ky Set = .002 inch per inch p. s. i.	Ultimate K p. s. i.	Elongation in 2 inches %	Ratio K/Ky	Ratio D/t
0.745	121,000	130,400	18.7	1.08	2
0.745	.....	194,000	12.0	....	2
0.250×1.50	103,500	120,030	19.5 F	1.16	6
0.250×1.50	123,000	140,500	17.0 F	1.14	6
0.250×1.50	171,000	189,420	11.5 F	1.11	6
0.020×0.750	104,000	115,180	14.5	1.11	37.5
0.020×0.750	130,000	142,700	9.0	1.10	37.5
0.020×0.750	167,000	184,610	4.0	1.11	37.5
0.029×1.50	95,000	116,980	12.5 F	1.23	51.7
0.029×1.50	132,000	143,350	14.5	1.09	51.7
0.029×1.50	171,000	187,310	8.0	1.10	51.7
0.034×2.50	96,000	114,380	12.0 F	1.19	73.5
0.039×2.50	131,000	145,000	6.5 F	1.11	64.1
0.034×2.50	171,000	187,200	4.5 F	1.09	73.5
0.020×1.50	132,000	146,930	9.5	1.11	75.0
	Data From Part I				
0.035×1.50	80,000	111,000	18.5	*1.39	43.0
0.035×1.50	120,000	128,700	13.0	1.07	43.0
0.035×1.50	143,500	157,200	7.5	1.09	43.0
0.035×1.50	182,500	198,100	6.5	1.08	43.0
0.049×1.50	91,000	126,700	16.5	*1.39	31.0
0.049×1.50	138,700	152,000	14.3	1.10	31.0
0.049×1.50	175,500	192,000	5.0	1.10	31.0
0.065×1.50	80,000	103,080	28.0	*1.29	24.0
0.065×1.50	88,200	123,400	21.5	*1.40	24.0
0.065×1.50	143,200	153,200	16.0	1.07	24.0
0.065×1.50	180,000	198,800	9.0	1.10	24.0
0.095×1.50	74,500	110,500	30.0	*1.48	16.0
0.095×1.50	122,000	130,070	21.0	1.06	16.0
0.095×1.50	151,500	156,000	16.0	1.03	16.0
0.095×1.50	185,500	194,700	11.0	1.05	16.0

NOTE.— F denotes standard flat specimen cut from tube.

* Normalized material only. All other heat-treated (quenched and drawn).

Fig. 5

Discussion

The tensile properties and the physical dimensions of the cylindrical sections are given in Table I. The tensile stress-strain curves in Fig. 3 show considerable plastic deformation before failure for all D/t ratios. The torsional stress-strain curves in Fig. 4 show little or no plastic deformation before failure for ratios of D/t greater than 6, irrespective of the ratio of L/D

The required number of test specimens of various lengths for a specific ratio of D/t and heat-treatment were obtained from the same length of tubing or bar, thus eliminating any effect of variation in material and in heat-treatment. The testing and heat-treatments were all made at Wright Field.

The types of failures noted in Fig. 5 are typical for the various D/t ratios irrespective of the L/D ratios.

Although the formula was developed from tests on heat-treated chrome-molybdenum material, it should be applicable to other heat-treated alloy steels that develop tensile properties comparable to the steel investigated.

Book Review

The Aircraft Year Book for 1936, edited by Howard Mingos; Aeronautical Chamber of Commerce of America, New York; 526 pages, $3.50.

The eighteenth annual edition of the Aircraft Year Book justifies its claim that it is the "standard authority and reference work for American aeronautics." Howard Mingos, who has edited the annual for many years, has presented in an easily read style an account of the progress of the art and science of American aircraft development during 1935.

The voluminous statistical tables and the division giving the personnel of organizations that are active in aeronautics are invaluable for reference.

Of particularly timely interest are the chapters devoted to the comparative strength of air forces of the leading air powers. There is no equivocation regarding the present position of the United States. For many years these comparisons have appeared in successive year books and have been accepted as presenting the approximate and relative status of the various countries. In the present volume particular attention is given to the vast program of aeronautical expansion in Germany. The products of the factories, the organization of the new German Air Force and the large programs of the laboratories and universities are described with surprising familiarity. The gist of these chapters is that the lead of the United States, which before 1935 was estimated to be three years in advance of other nations in the science of designing and constructing airplanes, has been reduced to about 18 months. The Year Book explains the reasons for this.

"It is not through any fault of American scientists or the members of the aircraft industry. They have carried on to the limit of their resources. But there are many forms of experimentation and development which no individual unit of an industry can afford to carry on; and there the Government must contribute, in two ways —one, by support which encourages and in part pays for constant improvement by the industry; two, through extensive Government research and experimentation in the pure science of aeronautics."

The United States is rated as fifth in number of Combat planes, being behind the British Empire, France, Russia and Italy but ahead of Japan and Germany. The prediction is made that by January 1937 the United States will have dropped to sixth place, having been passed by Germany, and will then have about the same combat air strength as Japan.

Of particular interest to aeronautical engineers will be the description of the new experimental laboratory of the D. V. L. at Adlershof, Germany; of the Etablissement d'Experiences Technique at Chalais-Meudon, France; and of the Italian Laboratory city of Guidonia.

No one who wishes to be familiar with the latest types of aircraft and aeronautical engines produced in this country or in the operation of the air transport companies can secure in any other book such complete and authentic information.

The illustrations throughout the volume are carefully chosen as usual and present a pictorial record of the progress of aircraft, engine and accessory design and operation. For those who are unfamiliar with this standard work the chapter headings follow:

Chapter I, Development of Air Power; Chapter II, The United States in the Air; Chapter III, Other World Air Powers; Chapter IV, With the Army Air Corps; Chapter V, The Navy's Air Forces; Chapter VI, The Flying Coast Guard; Chapter VII, Governmental Activities; Chapter VIII, State Aviation Activities; Chapter IX, Notable Flights of 1935; Chapter X, Air Lines in the United States; Chapter XI, Private Flying; Chapter XII, Aerial Service; Chapter XIII, Airways and Airports; Chapter XIV, Airships and Balloons; Chapter XV, Training and Education; Chapter XVI, Laws and Regulations; Chapter XVII, Engineering and Manufacturing. Following Chapter XVII, additional sections on: Aircraft and Engine Designs; Aviation Chronology and Records; Flying Facts and Figures; and an Aeronautical Directory, are included.

Operator Solutions in Airplane Dynamics

ALEXANDER KLEMIN and BENJAMIN F. RUFFNER, *New York University*

(Received April 21, 1936)

Summary

THE equations of motion of the airplane may be reduced to simultaneous linear differential equations with constant coefficients, but their solution still remains laborious. With modern "operator" methods, complementary and particular solutions can be found, and allowance for initial conditions can be made in one process and the mathematical work is reduced to manageable proportions. In this paper the method is set forth briefly, verified by recalculation of an investigation of gust effects and applied to a problem in airplane dynamics which is of practical interest: the longitudinal motion of an airplane when a gun with powerful recoil is fired.

Part I—Mathematical Basis

If the operator d/dt is written as D, a differential equation has the general form.

$$F(D)\,x = f(t) \tag{1}$$

The operator D can be treated precisely like an algebraic symbol, and hence, symbolically

$$x = f(t)\,/F(D) \tag{2}$$

The solution of the differential equation then resolves itself into the accurate evaluation of the expression $f(t)/F(D)$.

Significance of the Operator D^{-1}

If we have an equation $dx/dt = Dx = 1$,
then integrating between the limits $x = x_o$, $t = o$
and $x = x$, $t = t$

we have: $x - x_o = \int_o^t 1\,dt = t.$

Then $D(x - x_o) = Dx = D\int_o^t 1\,dt = 1$

so that: $D = 1/\int_o^t dt = 1/D^{-1}$

and: $D^{-1} = \int_o^t dt$ (3)

Significance of the Operator D^{-n}

Since $D^{-1}1 = \int_o^t 1\,dt = t$

$$D^{-2}1 = \int_o^t t\,dt = t^2/2$$

and: $D^{-n}1 = t^n/n!$ (4)

The Operator $D/D-\alpha$ where α is a constant

$D/D-\alpha$ is equivalent to $1/1-\alpha\,D^{-1}$ which can be expanded into the series. $1 + \alpha D^{-1} + \alpha^2 D^{-2} \ldots\ldots \alpha^n D^{-n}$.

Hence: $(D/D-\alpha)\,1 = 1 + \alpha t + \alpha^2 t^2/2! + \alpha^3 t^3/3! \ldots\ldots$

Finally: $D/D - \alpha = e^{\alpha t}$ (5)

Evaluation of Useful Operator Forms:

Other useful forms which are employed in this paper are as follows:

$$D/(D+\alpha) = e^{-\alpha t} \tag{6}$$

$$1/(D-\alpha) = e^{\alpha t}/\alpha - 1/\alpha \tag{7}$$

$$1/(D+\alpha) = 1/\alpha - e^{-\alpha t}/\alpha \tag{8}$$

$$\alpha/(D-\alpha) = e^{\alpha t} - 1 \tag{9}$$

$$\alpha/(D+\alpha) = 1 - e^{-\alpha t} \tag{10}$$

$$e^{\mu t}/(D-\alpha) = (1/\alpha - \mu)\,e^{\alpha t} - (1/\alpha - \mu)\,e^{\mu t} \tag{11}$$

$$e^{\mu t}/(D+\alpha) = (1/\alpha + \mu)\,e^{\mu t} - (1/\alpha + \mu)e^{-\alpha t} \tag{12}$$

Heaviside Identity if Roots are Real

The following identity, which may be demonstrated by appropriate algebraic expansions, is useful in the solution of simultaneous equations:

$$f(D)/F(D) = f(o)/f(o) + \sum_{\alpha}[f(\alpha)/\alpha F^1(\alpha)]\,e^{\alpha t} \tag{13}$$

where α represents the roots of the equation $F(D)=o$, in which D is regarded as an algebraic symbol, and in which all the roots are real.

$$[f(D)/F(D)]\,e^{\mu t} = [f(\mu)/F(\mu)]\,e^{\mu t} + \sum_{\alpha}[f(\alpha)/(\alpha-\mu)F^1(\alpha)]\,e^{\alpha t} \tag{14}$$

in which all the roots of F(D)=o are real.

Heaviside Identity, Complex Roots

In the equation f(D)=o, if there is a pair of complex roots of the form (a+ib) and (a—ib), then the sum of the two corresponding terms in the summation

$$\sum_{\alpha}[f(\alpha)/\alpha F^i(\alpha)]\,e^{\alpha t} \text{ of Eq. (13)}$$

$$\sum_{\alpha = a+ib,\ a-ib}[f(\alpha)\,e^{\alpha t}/\alpha F^1(\alpha)] = 2e^{at}/(a^2+b^2)\,(e^2+f^2)]$$
$$\times\{[a(ce+df) + b(de-cf)]\cos bt + [b(ce+df) - a(de-cf)]\sin bt\} \tag{15}$$

where:

$$c = f(a) - (b^2/2!)f^{ii}(a) + (b^4/4!f^{iv}(a) - (b^6/6!f^{vi}(a):$$

$$d = bf^i(a) - (b^3/3!)f^{iii}(a) + (b^5/5!)f^v(a)$$

$$e = F^i(a) - (b^2/2!)F^{iii}(a) + (b^4/4!)F^v(a) - (b^6/6!)F^{vii}(a)$$

$$f = bF^{ii}(a) - (b^3/3!)F^{iv}(a) + (b^5/5!)F^{vi}(a)$$

Similarly, the sum of two terms involving complex roots (a+ib) and (a—ib) in the expression:

$$\sum_{\alpha}[f(\alpha)/(\alpha-\mu)F^1(\alpha)]e^{\alpha t} \text{ of Eq. (14)}$$

$$\sum_{\alpha=a+ib,\,a-ib}[f(\alpha)e^{\alpha t}/(\alpha-\mu)F^1(\alpha)]$$

$$=[2e^{at}/[(a-\mu)^2+b^2](e^2+f^2)]$$

$$\times\{[a(ce+df)+b(de-cf)-\mu(ce+df)]\cos bt$$

$$+[b(ce+df)-a(de-cf)+\mu(de-cf)]\sin bt\} \quad (16)$$

where: c, d, e, and f have the same significance as before.

Solution by Operators with Initial Conditions Taken into Account:

The equations in which we are most interested are of the general type:

$$dx/dt = ax + f(t) \quad (17)$$

where: $x = x_o$ when $t = o$.

Applying D^{-1}, that is $\int_o^t$ dt to both sides of this equation:

$$\int_o^t (dx/dt)\,dt = x - x_o = D^{-1}ax + D^{-1}f(t)$$

from which: $x = x_o + D^{-1}(ax) + D^{-1}f(t) \quad (18)$

$$= x_o + \int_o^t (ax)\,dt + \int_o^t f(t)\,dt$$

If this is evaluated the complete solution for x with all constants of integration is at once available.

In the evaluation process it is more convenient, however, to eliminate D^{-1} by multiplying both sides of Eq. (17) by D. Then:

$$Dx = Dx_o + ax + f(t)$$

and: $(D-a)x = Dx_o + f(t)$

so that: $x = Dx_o/(D-a) + f(t)/(D-a) \quad (19)$

In the evaluation of the right hand side of the equation, the formulae previously given can be readily applied.

By analogy, we can say that, if,

$$F(D)x = f(t) \text{ and } x = x_o, \text{ when } t = O.$$

$$x = Dx_o/F(D) + f(t)/F(D) \quad (20)$$

and more broadly if $F(D)x = f(D)t$

$$x = Dx_o/F(D) + f(D)t/F(D) \quad (21)$$

Example in the Solution of Simultaneous Equations:

The following two equations provide a simple illustration of the method of solution:

$$\text{and} \quad \begin{matrix} \text{and } dx/dt + 3x + y = e^t \\ -2x + dy/dt = e^{2t} \end{matrix}$$

where: $x = x_o, y = y_o$ at time $t = o$.

The ordinary methods of solution by the elimination of y, obtaining the complementary solution, obtaining the particular solution, and introducing the initial conditions to find the initial conditions, give:

$$x = [2x_o + y_o - (11/12)]e^{-2t} + [-x_o - y_o + 5/6]e^{-t} + e^t/6 - e^{2t}/12$$

Changing the operator d/dt into D, we have:

$$(D+3)x + y = e^t$$

$$-2x + Dy = e^{2t}$$

To take care of initial conditions, we use Eq. (19), in modified form, and write:

$$\text{and} \quad \begin{matrix} (D+3)x + y = Dx_o + e^t \\ -2x + Dy = Dy_o + e^{2t} \end{matrix}$$

so that:

$$x = \frac{\begin{vmatrix} Dx_o + e^t & 1 \\ Dy_o + e^{2t} & D \end{vmatrix}}{\begin{vmatrix} D+3 & 1 \\ -2 & D \end{vmatrix}} = \left\{ \begin{matrix} \dfrac{D^2x_o}{(D^2+3D+2)} - \dfrac{Dy_o}{(D^2+3D+2)} \\ + \dfrac{De^t}{(D^2+3D+2)} - \dfrac{e^{2t}}{(D^2+3D+2)} \end{matrix} \right\}$$

To evaluate $(D^2x_o - Dy_o)/(D^2+3D+2)$ we use Eq. (13)

$$\frac{D^2x_o - Dy_o}{(D^2+3D+2)} = \frac{f(D)}{F(D)} = \frac{f(o)}{F(o)} = \sum_{\alpha}\left(\frac{f(\alpha)}{\alpha F^1(\alpha)}\right)e^{\alpha t}$$

Since the roots of F(D)=o are =—1, and =—2, we have

$$\frac{D^2x_o - Dy_o}{(D+1)(D+2)} = O + \left[\frac{x_o + y_o}{(-1)(-2+3)}\right]e^{-t} + \left[\frac{4x_o + 2y_o}{(-2)(-4+3)}\right]e^{-2t}$$

$$= -(x_o + y_o)e^{-t} + (2x_o + y_o)e^{-2t}$$

To evaluate $De^t/(D+1)(D+2)$ we use Eq. (14) and

$$\left[\frac{D}{(D+1)(D+2)}\right]e^t = \left[\frac{f(1)}{F(1)}\right]e^{1t}\left[\frac{(-1)e^{-t}}{(-2)(-1)}\right] - \left[\frac{(-2)e^{-2t}}{(-3)(-4+3)}\right]$$

$$= (e^t/6) + (e^{-t}/2) - (e^{-2t}/3)$$

To evaluate $-e^{2t}/(D+1)(D+2)$ we write in the form:

$$-f(D)e^{2t}/(D+1)(D+2) \text{ when } f(D) = D^o$$

and, again we use Eq. (14). Then:

$$-e^{2t}/(D+1)(D+2) = -[e^{2t}/12 + e^{-t}/(-3)(1) + e^{2t}/(-4)(-4+3)] = -(e^{2t}/12) + (e^{-t}/3) - (-e^{2t}/4)$$

A summation of these calculations give the same answer:

$$x = [2x_o + y_o - (11/12)]e^{-2t} + [-x_o - y_o + (5/6)]e^{-t} + (e^t/6) - (e^{2t}/12)$$

as did the classical method of solution.

General Form of Solution for Simultaneous Linear Differential Equations

The above process of solving simultaneous equations can be extended to any number of equations.

Thus, if, when $t=o, x=x_o, y=y_o$ and $z=z_o$, and

$$a_1 Dx + b_1 y + C_1 z = f_1(t)$$
$$a_2 x + b_2 Dy + c_2 z = f_2(t)$$
$$a_3 x + b_3 y + c_3 Dz = f_3(t)$$

we can write:

$$a_1 Dx + b_1 y + c_1 z = Dx_o + f_1(t)$$
$$a_2 x + b_2 Dy + c_2 z = Dy_o + f_2(t)$$
$$a_3 x + b_3 y + c_3 Dz = Dz_o + f_3(t)$$

and:

$$x = \frac{\begin{vmatrix} Dx_o + f_1(t) & b_1 & c_1 \\ Dy_o + f_2(t) & b_2 D & c_2 \\ Dx_o + f_3(t) & b_3 & c_3 D \end{vmatrix}}{\begin{vmatrix} a^1 D & b_1 & c_1 \\ a_2 & b_2 D & c_2 \\ a_3 & b_3 & c_3 D \end{vmatrix}} = \frac{\begin{vmatrix} Dx_o + f_1(t) & b_1 & c_1 \\ Dy_o + f_2(t) & b_2 D & c_2 \\ Dz_o + f_3(t) & b_3 & c_3 D \end{vmatrix}}{\Delta} \quad (22)$$

and x can be evaluated by the usual methods. Similar expressions can be written for y and z.

Part 2—Verification of Accuracy of Operator Methods

The problem of an airplane encountering gusts has been treated by E. B. Wilson in early N.A.C.A. reports, and his work offers one of the few published examples of the solution of the equations of motion with impressed forces by the classical differential equation methods.

These reports dealt with an airplane encountering gusts represented by the function $J(1-e^{-rt})$ so that the gusts reached a maximum intensity J. Since Wilson's calculations were merely repeated for the sake of verifying the validity, rapidity, and arithmetical accuracy of the operator method, it is sufficient simply to set down the results of this comparative work:

(1) The modern operator method appears to be more rapid.

(2) The modern operator requires less special manipulation in determining the constants of integration, and can be carried out in more systematic, more readily tabulated form.

(3) The operator method is more accurate, and solutions give better check with initial conditions.

In a given case, Wilson's solution to the variations in longitudinal velocity for a given gust was:

$$u = J e^{-.0654t}(.622 \cos .187t + .630 \sin .187t) - J(1 - .24 e^{-2t}).$$

So that at time t=o, u=J(.133), when it should have been zero. The solution obtained by the operator method was:

u=J(.00285) at time t=o, a value which is not far from being zero.

Part 3—Longitudinal Motion of an Airplane Disturbed by Recoil of a Heavy Gun

Recently, relatively large sized guns have been developed for aircraft use. These guns have been fully tested and appear satisfactory. Prior to the actual use of these guns on aircraft, constructors naturally brought up the question: What will be the effect on the stability of the airplane when it is subjected to the recoil of these large guns?

Since the solution of this problem is admirably adapted to the operator methods, the following basic assumptions were made and the solution was carried through.

The standard system of axes is used for writing the equations of motion, as in N.A.C.A. Report No. 1, (Reference 3).

The airplane chosen for computations was one having general dimensions, weights, etc., equal to those of the Curtiss Falcon. Since no derivatives were available for this airplane, such derivatives were calculated by assuming the airplane geometrically similar to the J. N. 2, for which complete data is available in N.A.C.A. Report No. 1. While the Falcon is a more modern airplane than the J. N. 2, and the derivatives obtained in this manner might not be accurate for the Falcon, the derivatives are, nevertheless, those of an airplane of reasonable characteristics.

In order to calculate the effect of the gun, it was assumed mounted at a distance of seven feet behind the center of gravity, and firing vertically upwards. The gun chosen was one which fired forty shots per minute with a recoil per shot of 1000 lbs., lasting for .3 second. The average force applied to the airplane was then found to be 200 lbs., acting vertically downwards, while the gun was in use.

The data used in the computations was then as follows, where all derivatives are referred to unit mass:

Gross weight	4,700 Lbs.
Mass in slugs	146.2
Span	38 feet
Length	27′ 7″
Wing Area	348 Sq. Ft.
Maximum speed	172 m.p.h.
X_u	—.0739
X_w	.0935
X_q	0
U	252 ft./sec.
Z_u	—.323
Z_w	—.228

Z_u 0

Z_θ Vertical force due to gun $= -200/146.2 = -1.37$

M_u 0

M_w 1.40

M_q ..... −160.0

M_θ (Moment due to gun $= (1400/146.2)$ .. 9.56

K_B^2 ..... 38.6

The equations of motion along the x axis, along the z axis, and about the OY axis are then as follows:

$$(D - X_u)\,U - X_w\,W - (X_q\,D + g)\,\theta = 0$$
$$-Z_u\,U + (D - Z_w)\,W - (Z_q + U)\,D\,\theta = Z_\theta$$
$$-M_u\,U - M_w\,W + (K_B^2\,D^2 - M_q\,D)\,\theta = M_\theta$$

The symbolical solution is then

$$\theta = \frac{\begin{vmatrix} 0 & (D - X_u) & -X_w \\ Z_\theta & Z_u & (D - Z_w) \\ M_\theta & -M_u & -M_w \end{vmatrix}}{\begin{vmatrix} D - X_u & -X_w & -(X_q D + g) \\ -Z_u & (D - Z_w) & -(Z_q + u)\,D \\ -M_u & -M_w & (K_B^2\,D^2 - M_q\,D) \end{vmatrix}} = f(D)\,/\,F(D)$$

Expansion of these determinants then gives:

$$f(D) = Z_\theta\,(M_u\,X_w + D\,M_w - M_w\,X_u) + M_\theta\,[(D - X_u)\,(D - Z_w) - X_w Z_u]$$

$$F(D) = (D - X_u)\,[(D - Z_w)\,(K_B^2\,D^2 - M_q\,D) - M_w\,U\,D] - Z_u\,[M_w g + X_w\,(K_B^2\,D^2 - M_q\,D)]$$

Substituting in the numerical value of the derivatives, the expressions become:

$$f(D) = 9.56\,D^2 - 2.103\,D + 1.683$$

$$F(D) = 38.6\,D^4 + 250.8\,D^3 + 736.3\,D^2 + 57.8\,D + 14.54$$

Solving for the roots of F(D)=O by conventional methods the four following roots were obtained:

$$\alpha_1 = -3.2095 + 2.891\ i$$
$$\alpha_2 = -3.2095 - 2.891\ i$$
$$\alpha_3 = -\ .0365 + \ .1404\ i$$
$$\alpha_4 = -\ .0365 - \ .1404\ i$$

The evaluation for $f(D)/F(D)$ was then carried out by use of Eqs. (13) and (15), giving the equation:

$$\theta = .1158 + e^{-3.2095\,t}\ (-.0149 \cos 2.891\ t - .0144 \sin 2.891\ t) + e^{-.0365\,t}\ (-.1009 \cos .1404\ t - .0482 \sin .1404\ t)$$

By similar processes, the following equation of the velocity along the OZ axis was obtained:

$$W = -6.828 + e^{-3.2095\,t}\ (3.052 \cos 2.891\ t + 2.834 \sin 2.891\ t) + e^{-.0365\,t}\ (3.62 \cos .1404\ t + .726 \sin .1404\ t)$$

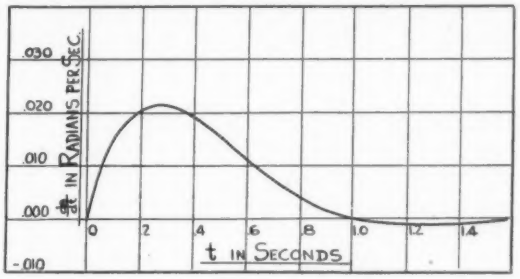

Fig. 1.

The angular velocity is pitch $d\theta/dt$ is obtained by differentiation of the expression for θ.

$$d\theta/dt = e^{-3.2095\,t}\ [.00518 \cos 2.891\ t + .08928 \sin 2.891\ t] + e^{-.0365\,t}\ [-.00309 \cos .1404\ t + .01592 \sin .1404\ t]$$

In Fig. 1 is plotted a curve of $d\theta/dt$ vs. time. This curve shows a maximum pitching velocity of .022 radians per second at the end of .28 seconds. Since this is equivalent to only 1.27 degrees per second, it is not believed that this disturbance of the motion would seriously effect the accuracy of firing the gun. It has also been assumed that the pilot has made no effort to actuate the controls to counteract the effect of the recoil, so that, in actual operation with an alert pilot, the disturbance would be something less than that indicated in the figure. The final attitude of the airplane after several seconds of firing would be different than the initial conditions with gun not in action. The effect of the gun recoil as considered here would be that of temporarily adding a weight to the airplane, equal to the average recoil, at a distance of seven feet behind the center of gravity.

While the final path of the airplane if the gun is continuously fired would be different from the initial path with the gun not in operation, it is reasonable to say that the accuracy of gun fire depends not on the final path, but the rate of change of the direction of motion which is the pitching velocity. Since this maximum pitching velocity is small, the accuracy of gun fire should not be impaired.

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[2] L. W. Bryant and D. H. Williams. *The Application of the Method of Operators to the Calculation of the Disturbed Motion of an Aeroplane,* British R. & M. No. 1346.

[3] J. C. Hunsaker. *Experimental Analysis of Inherent Langitudinal Stability for a Typical Biplane,* N.A.C.A. Technical Report No. 1, Part 1.

[4] E. B. Wilson. *Theory of an Aeroplane Encountering Gusts,* N.A.C.A. Technical Report No. 1, Part 2.

The Lawrence B. Sperry Award for Young Men

LAWRENCE B. SPERRY

An award in memory of Lawrence B. Sperry will be given annually under the direction of the Institute for outstanding achievements in aeronautics by young men.

The "Lawrence B. Sperry Fund" of $10,000 will be provided by Elmer A. Sperry, Jr., Edward G. Sperry, and Helen Sperry Lea, brothers and sister of Mr. Sperry, who was drowned in attempting a flight across the English Channel on December 13, 1923. The Fund, which will be administered by the Institute, will give a certificate and $250 in cash to a young man who, in the opinon of the Award Committee, has made "the greatest contribution to the advancement of aeronautics during the year for which the award is presented." The donors have chosen as the Committee to select the recipient for 1936, Grover Loening, Glenn L. Martin, Charles L. Lawrance, Major James H. Doolittle, Elmer A. Sperry, Jr., and Major Lester D. Gardner.

The conditions to be fulfilled by the recipients are to be decided after a conference between the donors and the Fund Committee.

Lawrence B. Sperry, pioneer in blind flying and air navigation, who was the son of Elmer A. Sperry, the distinguished scientist whose name will always be associated with gyroscopic instruments, was born December 21, 1893. In 1909 he built his first airplane and two years later developed and tested the gyroscopic stabilizer for airplanes which won the first prize in the French Airplane Security Contest held near Paris in 1914. The present day airplane gyropilot is a direct development of these early experiments. He invented a radio controlled aerial torpedo plane and developed it so that it made hundreds of cross-country flights. He was one of the first group of pilots to join the U. S. Naval Flying Corps in 1917. The Messenger planes which he built and flew performed many of the earliest recorded landings in city streets and demonstrated the possibilities of refueling in flight. He also built quick release landing gears and was among the earliest users of skis on airplanes. His many pioneering aeronautical achievements before his death at the age of thirty years make such an award highly appropriate for young men.

The Daniel Guggenheim Medal Awarded to Dr. George W. Lewis

Dr. George W. Lewis, a Vice-President and Fellow of the Institute of the Aeronautical Sciences, has been honored by being selected as the recipient of the Daniel Guggenheim Medal for this year, *"For outstanding success in the direction of Aeronautical research, and for the development of original equipment and methods."*

At the Annual Meeting of the Daniel Guggenheim Medal Fund held on Wednesday, May 6th, the charter of the Fund was amended to include representation of three Directors to represent the Institute of the Aeronautical Sciences, three from the American Society of Mechanical Engineers, and three from the Society of Automotive Engineers. Under the new arrangement, the Directors for 1936 will be Rear Admiral E. S. Land, Major E. E. Aldrin, Thomas A. Morgan, C. H. Chatfield, Major Temple Joyce, Prof. Baldwin M. Woods, Glenn L. Martin, Sherman M. Fairchild and T. P. Wright.

Major E. E. Aldrin was reelected President; Sherman M. Fairchild, Vice-President; Major Lester D. Gardner, Secretary; and John H. R. Arms, Treasurer.

DR. GEORGE W. LEWIS

Institute Notes

I. Ae. S. Meeting at Rochester, June 16–18

At a session of the Summer Meeting of the American Association for the Advancement of Science of which the Institute is an affiliated society, the subject of "Aerial Photogrammetry" will be considered by the presentation of papers and discussions. The meeting will be held in the Lattimore Building at the University of Rochester on June 17, 1936, at 9:30 a.m. and conclude at 12:30 p.m. The Eastman Kodak Company has invited the members of the Institute to be its guests in the afternoon on a visit to the research laboratories at Kodak Park. The Rochester Committee in charge of the arrangements for the meeing are Dr. Walter Clark, Eastman Kodak Company; Carl Bausch, Bausch & Lomb Optical Co., and Dr. Edward Hoffmeister, University of Rochester.

The American Society of Photogrammetry of which H. H. Blee, a member of the Institute is President, will join with the Institute in sponsoring the meeting. The interest in this development of a combination of surveying and aerial photography has grown in this country during the past few years and in 1934 the American Society of Photogrammetry was organized.

Papers covering new developments as well as the major problems of the science will be presented at the meeting. The necessity of mapping large areas more quickly and with greater economy has brought about the employment of aerial photography in connection with surveying. Special equipment of cameras and plotting machines have been developed for this highly specialized work both in this country and abroad.

Lt. O. S. Reading of the U. S. Coast and Geodetic Survey, who is to be one of the speakers at the meeting, is responsible for the development of the latest type of multi-lens camera. This camera has nine lenses which record on one piece of film twenty-four inches square areas as large as five hundred square miles from an altitude of twenty thousand feet.

The United States Government is using aerial photography in practically all its major mapping problems. The Soil Conservation Service is mapping vast areas in connection with its problems. Marshall S. Wright, in charge of this service, will describe the methods used in making planimetric and contour maps.

The research work done by the Army Air Corps at Wright Field in the use of aerial photographs for producing certain maps by an aeroprojector will be discussed by Captain Louis J. Rumaggi of the Corps of Engineers, U. S. Army.

Other important problems such as films, lens requirements and apparatus specially adapted to photogrammetry as well as the final use of maps made by aerial photography will be discussed by other speakers.

Mr. Leon T. Eliel of the Fairchild Aerial Surveys, Inc., will preside.

The entire program is as follows:

PROGRAM

Lt. O. S. Reading, U. S. Coast and Geodetic Survey, Washington, D. C.
"Photogrammetry in 1936"

Marshall S. Wright, U. S. Soil Conservation Service, Washington, D. C.
"Planimetric Maps or Contour Maps"

Dr. Walter Clark, Eastman Kodak Co., Rochester, N. Y.
"Materials for Aerial Photography"

Dr. W. B. Rayton, Bausch & Lomb Optical Co., Rochester, N. Y.
"Lens Requirements for Photogrammetry"

Col. C. H. Birdseye, Chief of Bureau of Engraving & Printing, U. S. Geological Survey, Washington, D. C.
"Map Reproduction"

Capt. Louis J. Rumaggi, Corps of Engineers, U. S. Army, Dayton, O.
"The Multiplex Aeroprojector"

Charles W. Collier, U. S. Soil Conservation Service, Washington, D. C.
"Use of Aerial Maps in Soil Conservation Studies"

Student Branches

University of Michigan. A third meeting of this Student Branch was held Thursday, April 30th, in the East Engineering Building of the University. The meeting was conducted as a seminar, the topic of discussion being "Structures."

Edmund L. Ryder of the Department of Aeronautical Engineering, gave a talk on "The Aim of the Department of Commerce Toward the Development of Better Aircraft Design." He described the necessary work of the manufacturers before the Department of Commerce granted an Approved Type Certificate. The talk was concluded with a discussion of the proposed changes in the Department of Commerce Bulletin regarding stress analysis requirements . . . etc.

Donald Bard, senior student, discussed the use of forgings in aircraft, giving the reasons for their use and the main difficulties involved.

Adam T. Zahorski, graduate student, presented a solution for the shear distribution in tubular cantilever beams. Shear distribution for various shapes was taken up, finally giving an exact solution of shear distribution for circular rings.

Robert M. Harrison, a senior student, presented a summary of data concerning general practices in welding and riveting. He discussed the general practice of spot welding of various metals, and also discussed the methods used in making extruded sections, used in aircraft structures.

Carnegie Institute of Technology. A meeting of this Student Branch was held April 2nd. Victor Saudek talked on "Long Range Gliding," and Philip Bright on "Experiences of the Amateur Pilot." After the two student talks Professors Thorp and Blaisdell discussed the importance of individual research in obtaining employment.

Louisiana State University. At a meeting of this recently organized Student Branch, Lt. J. P. Fraim, Jr., was nominated as Honorary Chairman. A Constitution and By-Laws were adopted. Provisions were incorporated in the By-Laws for sending a delegate each year to the Annual Meeting of the Institute.

Forthcoming meetings were discussed, and it was planned to have speakers at each meeting, after which there will be an open discussion on the subject presented. An inspection trip to the Naval Air Base at Pensacola, Florida, under the supervision of the school, is planned.

University of Detroit. A meeting of this branch was held Thursday, May 7th, in the Engineering Building of the University. Carl B. Fritsche, of the Metalclad Airship Company, spoke of "Airships Today and Tomorrow." Robert B. Evans, of the E. S. Evans and Sons General Appliance Company, spoke on "Hydro-vanes for Water Craft."

Book Reviews

Hydrodynamics; Bulletin No. 84 of the National Research Council, (Report of the Committee on Hydrodynamics of the Division of Physical Sciences), 1932.

The Institute has recently added to the library this encyclopaedic review of hydrodynamics which is intended as a supplement to the classic treatise of Lamb. The report begins with a brief survey of experimental aerodynamics by Hugh L. Dryden, in which the types of flow now susceptible to theoretical treatment are outlined. Francis D. Murnaghan then gives briefly the theory of perfect fluids as applied to forces on airfoils. The greater part of the report is devoted to viscous fluids in laminar flow, to turbulent flow, and to compressible fluids, contributions of H. Bateman.

A very wide field is covered, including for example such diverse topics as viscometry, theory of lubrication, heat transfer, transport of silt by rivers, propagation of sound waves, flow in pipes and channels, and diffusion as well as numerous topics of more immediate interest to aeronautical engineers, such as boundary layer theory, fluid friction, turbulence, etc. As a consequence, the space devoted to any one topic is limited. The theory of the laminar boundary layer and its applications is covered in fifteen pages; that of the turbulent boundary layer in seven.

References are given to more than 2500 papers and books. The report thus serves as an extended bibliography, topically arranged. The aeronautical engineer will find this feature extremely useful in determining what has been done in some unfamiliar field.

The emphasis of the report is, in general, on the theoretical aspects of hydrodynamics, although numerous references are given to papers dealing with results of experiment. Diverse points of view are presented, reflecting the state of devlopment of the subject.

The aeronautical engineer who is interested in the theory of his art will include this volume among his reference books.

HUGH L. DRYDEN

Rockets Through Space, by F. E. CLEATOR; Simon and Schuster, New York, 1936; 228 pages, ill., $2.50.

This popular science book deals with the problems of interplanetary flight, and describes what has been done and what is being done toward the realization of man's desire to reach other planets. While written for the layman, it gives much general and technical information on the subject, with references to the scientific studies that have been made. Interest in the practical development of the rocket has been growing in nearly every country since the discovery by German experimenters in 1929 that liquid-oxygen and gasoline could be mixed and burned continuously, the rapid evolution of gases resulting in a powerful jet reaction. From the many ideas on space flight since ancient times, points out the author, the first really scientific theory was that proposed in 1903 by Konstantin E. Ziolkovsky, a Russian author-scientist, who showed that rocket propulsion is effected purely by jet reaction, and therefore would function in the vacuum of space.

The book traces the evolution of the rocket motor (combustion chamber and exhaust nozzle) from the thousand year old gunpowder burning and paper cased type to the modern water-cooled gasoline-burning motor. Dr. Robert H. Goddard in America, Professor Hermann Oberth in Germany, and Robert Esnault-Pelterie in France were among the pioneers of modern rocketry, and made outstanding contributions to the subject. The uncontrollability of gunpowder, together with its low energy content and combustion efficiency were the principal deterrents to progress in this field. With the powerful new liquid rocket fuel made available, the interplanetary idea seemed more attractive, and research was begun and continues today by the Verein fur Raumschiffahrt (Society for Space Navigation) in Germany, and by the American Interplanetary Society (now the American Rocket Society) here in America. These and other groups in various other countries organized for the sole purpose of developing the rocket and making their findings mutually available. What they have accomplished up to the present is to bring out clearly the many difficult engineering problems which must be solved before space flight is to become practical.

Principal among these is the problem of obtaining enough kinetic energy from the fuel to accelerate the rocket to the earth's "parabolic escape velocity" of 7 miles per second. This velocity is required to make the trajectory an infinitely receding parabola, instead of the familiar projectile's path, an arc of an ellipse which must invariably return to earth. While the attainment of this velocity is theoretically possible with the "step-rocket," in which 20 tons of final weight would require 4,380 tons of the fuel, it is evidently impractical at present. Other problems discussed in the book are the difficult handling of the terrific temperatures of the oxygen-fed flame, suitable light and strong materials for construction, the effect of initial acceleration and lack of gravity in space on the human body, methods of navigating in space, of landing and returning from planets. The increasing attention being directed to the serious experiments of the American Rocket Society in New York, and of Dr. Goddard (who received a grant from the Guggenheim Foundation last fall to continue his experiments in New Mexico) makes this a book worth reading as an introduction to the subject.

ALFRED AFRICANO

Hours, Wages and Working Conditions in Scheduled Air Transportation, by JOSEPH B. EASTMAN, Federal Coordinator of Transportation; Washington, March, 1936; 155 pages.

This report which was prepared by the Research Section of the Federal Coordinator of Transportation, Joseph B. Eastman, is the most complete study ever made of the status of employees of air transport companies. In a Foreword Mr. Eastman states that the report was prepared so that comparisons could be made with the labor conditions and relations of other means of transportation. The many tables analyse practically every phase of wages, hours and working conditions in the air transport industry. The comment and suggestions make the report a standard reference work on labor relations of pilots, mechanics, stewardesses and other employees of the air lines.

Exchanges

The Institute exchanges the Journal with many other aeronautical periodicals. They are kept on file at the Skyport in Rockefeller Center, New York City, where members may read them. As readers of the Journal may wish to subscribe to some of them, a list of these periodicals with their addresses is published here. Information regarding subscription prices may be secured from the Secretary of the Institute.

Aero, Maneesikatu 2, Helsingfors, Finland.

Aero Digest, 515 Madison Ave., New York City.

Aeronautica Argentina, Velez Sarsfield 57, Cordoba, Argentina.

L'Aeronautique, 55 Quai des Grands-Augustins, Paris, France.

L'Aerophile, 7 Rue Saint-Lazare, Paris, France.

The Aeroplane, 175 Picadilly, London, W.1, England.

L'Aerotecnica, Via delle Coppelle 35, Rome, Italy.

Les Ailes, 77 Boulevard Malesherbes, Paris, France.

Aircraft Engineering, 112 Bunhill Row, London, E.C.1, England.

Air Law Review, Washington Square East, New York City.

Asas, Caixa Postal 1967, Rio de Janeiro, Brazil.

Aviation, 330 West 42nd St., New York City.

Aviation Weekly, 9401 Western Ave., Los Angeles, California.

L'Aviazione, Corso Umberto 504, Rome, Italy.

Boletin de Aeronautica Civil, Calle Azcuenaga 923, Buenos Aires, Argentina.

Boletin Oficial de la Direccion General de Aeronautica, Magdalena 12, Madrid, Spain.

Bulletin du Service Technique de l'Aeronautique, 72 chaussee de Waterloo, Rhode-Saint-Genese, Belgium.

Bulletin Technique du Bureau Veritas, 31 rue Henri-Rochfort, Paris (17), France.

Canadian Aviation, Journal Building, Ottawa, Canada.

Deutsche Luftwacht, Schoeneberger Ufer 46, Berlin W35, Germany.

Envol, 22 rue Armand-Moisant, Paris (15), France.

Les Fiches Aeronautiques, 6 rue Galilee, Paris, France.

Flight, Dorset House, Stamford St., London, S.E.1, England.

Flugwesen, Konviktska 22, Prague 1, Czechoslovakia.

Indian Aviation, P. O. Box 2361, Calcutta, India.

Journal of Air Law, Northwestern University, Chicago.

Journal of the Institute of Engineers, Australia, Science House, Gloucester and Essex Sts., Sydney, N. S. W., Australia.

Journal of the Royal Aeronautical Society, 7 Albemarle St., Piccadilly, London, W.1, England.

Journal of Scientific Instruments, 1 Lowther Gardens, Exhibition Rd., London, S.W.7, England.

Journal of the Society of Automotive Engineers, 29 West 39th St., New York City.

Luftfahrt-Forschung, Verlag Oldenbourg, Munich 1, Germany.

Die Luftreise, Lindenstr. 35, Berlin SW68, Germany.

Luftfahrt-Literaturschau, Z.W.B. bei der D.V.L., Berlin-Adlershof, Germany.

Model Airplane News, 551 Fifth Avenue, New York City.

Monthly Weather Review, U. S. Dept. of Agriculture, Washington, D. C.

Motor and Flying, 24 Bond St., Sydney, N. S. W., Australia.

National Aeronautic Magazine, Dupont Circle, Washington, D. C.

Official Aviation Guide, 608 S. Dearborn St., Chicago.

The Pilot, Grand Central Air Terminal, Glendale, California.

Il Politecnico, Via Spiga 32, Milan (2/7), Italy.

Popular Aviation, 608 S. Dearborn St., Chicago.

Proceedings of Institute of Radio Engineers, 330 W. 42d St., New York City.

Review of Scientific Instruments, 175 Fifth Ave., New York City.

Revista de Aeronautica, Ministerio de la Guerra, Apartado 1047, Madrid, Spain.

Revue de l'Armee de l'Air, 55 quai des Grands-Augustins, Paris, France.

Revue du Ministere de l'Air, 71 avenue des Champs-Elysees, Paris, (8), France.

Rivista Aeronautica, Ministero dell'Aeronautica, Rome, Italy.

The Royal Air Force Quarterly, Gale & Polden Ltd., 2 Amen Corner, London, E.C.4, England.

Southwestern Aviation, Ledger Building, Fort Worth, Texas.

Sportsman Pilot, 515 Madison Ave., New York City.

Technika Vosdushnogo Flota, Ul. Radio 16, Moscow 16, U. S. S. R.

La Technique Aeronautique, 2 rue Blanche, Paris (9), France.

U. S. Air Services, Transportation Building, Washington, D. C.

Western Flying, 420 S. San Pedro St., Los Angeles, California.

Wirtschaft Technik Verkehr, Alte Jakobstr. 148/155, Berlin SW68, Germany.

Zeitschrift für angewandte Mathematik und Mechanik, Kulmstr. 1, Dresden A24, Germany.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps. The articles listed may not be obtained from the Army Aeronautical Museum Library as these magazines are available to Wright Field personnel only.

Aerodynamics

Aerodynamical Research and Hydraulic Practice. A. Fage. Research on fluid motion undertaken in aerodynamical laboratories and its bearing on problems of hydraulic practice. The influence of boundary layer flow on resistance and flow phenomena is indicated. Methods of controlling flow by the use of guide vanes, slots, boundary jets, fairings and other devices are described and attention is directed to features of wind-tunnel design favoring steadiness of flow. Theoretical and experimental research undertaken to obtain an insight into the mechanism of fully developed turbulence is referred to and the latest resistance formula given for a smooth flat plate together with resistance curves for pipes having a specific form of surface roughness. Modern developments of the theory of a perfect fluid and applications to problems of a real fluid are outlined and a method given for designing axial-flow reaction turbines and pumps on lines suggested by airfoil theory. Thirty-five page paper followed by thirty pages of discussion by such people as L. Bairstow, H. S. Hele-Shaw and Cave-Brown-Cave. Institution Mechanical Engineers, Proceedings, April-October 1935, page 3.

The Boundary Layer. Critical survey of the present situation in the development of boundary layer investigation, recently given by L. Bairstow before the Royal Aeronautical Society, is discussed editorially. Engineering, March 27, 1936, page 347.

Boundary Layer Flow. H. B. Squire. Flow along a flat plate and effect of pressure gradient on the transition of the boundary layer from laminar to turbulent and on breakaway. Very brief abstract of British Aeronautical Research Committee Reports and Memoranda No. 1664. Mechanical Engineering, April 1936, page 246.

Conception of Air Resistance. M. M. Munk. Reduction of air resistance is taken up in a brief general discussion of the problem. Tangential resistance should be reduced as well as resistance normal to the surface and it is a mistaken belief that normal force resistance corresponds to, or is caused by, mass forces, and that the tangential force resistance corresponds to and is caused by air friction. Aero Digest, April 1936, page 25.

Application of the Results of Wing Model Measurements. F. Weinig. Application to the calculation of wings and turbo-machinery blades. By means of the conversion formulas given for the angle of attack, lift coefficients may be obtained which are said to agree generally with the results of the potential theory as these were mostly assumed. The remaining deviations can easily be explained by the small amount of flow at the trailing edge based on the assumption of Kutta and Joukowski in regard to the asymetrical downflow of the boundary layer. V.D.I., March 14, 1936, page 299.

Pressure Losses in Rectangular Elbows. R. D. Madison and J. R. Parker. Pressure loses as affected by radius and aspect ratios of the elbows, angle of bend, elbow size, velocity of flow, splitters in the elbows, and compound elbows. Transactions A.S.M.E., April 1936, page 167.

Digests of Papers on Aerodynamics. Operator Solutions in Airplane Dynamics, A. Klemin and B. F. Ruffner. Study of Mixing Between a Jet of Fluid of Various Densities and Still Fluid, H. Peters and J. Bicknell. The Whirling Arm in Aeronautical Research, T. Troller. Abstracts. Journal of the Aeronautical Sciences, March 1936, page 178.

Span Load Distribution on a Tapered Wing as Affected by Partial Span Flaps from Tests in the Full-Scale Tunnel. J. F. Parsons. Effect of flap span upon span load distribution, and lateral center-of-pressure location on a tapered wing as well as the effectiveness of extending the flap span. In addition to the experimental data two methods of theoretical analysis are presented in an attempt to generalize the experimental results. Journal of the Aeronautical Sciences, March 1936, page 161.

On the Stalling of Highly Tapered Wings. C. B. Millikan. Highly tapered wings tend to stall first near the tip and it appears that if the initial stall is sudden and just at the tip, there may result a sharp premature drop in the lift. Results of measurements made at fairly large Reynolds Number in the California Institute of Technology 10-foot wind tunnel on two highly tapered wings are discussed and compared with those obtained by Nazir. An extraordinarily sharp break in the curves for one wing was found at about 13 degrees, while the curves for the other with the same taper but different aspect ratio and airfoil section distribution indicated absolutely no such break. Journal of the Aeronautical Sciences, March 1936, page 145.

A Survey of Aerodynamics. Problems in aerodynamics actively pursued in the past year, C. B. Millikan. Experimental techniques for studying turbulent air flow, H. L. Dryden. Summary of work done at Langley Field along theoretical lines, T. Theodorsen. Abstracts. Journal of the Aeronautical Sciences, March 1936, page 173.

Airplane Design

Aircraft Sessions. "Everyman's Airplane—A Development towards Simpler Flying," F. E. Weick. "Smart Airplanes for Dumb Pilots," O. C. Koppen. "Engine Nacelles and Propeller and Airplane Performance," D. H. Wood. Abstracts of Annual Meeting papers. S.A.E. Journal, February 1936, page 38.

Airplane Design Needs for Unskilled Pilots. O. Koppen. Control requirements in the design of airplanes, about which there is general agreement. Abstract of paper presented at the Annual Meeting. S.A.E. Journal Transactions, February 1936, page 69.

Automatic Stabilization. F. Haus. Automatic lateral stabilizers are classified and automatic directional stability discussed. Secondary aerodynamic action of the lateral controls, utilization of the angle of slip, and use of the azimuth in automatic directional stability are taken up. The SECAT earth inductor compass, Siemens directional stabilizer, and the Askania pneumatic repeating compass are described in detail. Continuation of serial. L'Aeronautique, L'Aerotechnique Supplement, February 1936, page 17.

The Breguet Gyroplane. Parts of the rotor hub and automatic control for the pitch of the blades are illustrated and described briefly. L'Aerophile, February 1936, page 42.

The Dynamic Phenomena in Wings. Paul and Maurice Richard. The more general motion of an airplane, dynamics of the plane in an irregular wind and influence of the structure are discussed and general equations given for inertia, mechanical elasticity, aerodynamics, and similitude of the phenomena. Conclusion of article dealing with the influence of elasticity on the nature and development of the dynamic phenomena. L'Aerophile, February 1936, page 38.

An Electrical Device for Solving the Equations of Longitudinal Stability. R. K. Mueller. Machine for solving longitudinal stability equations, as well as the effect upon airplane stability of a few typical design variations, including:—the character of motion after a fixed disturbance at cruising speed (140 mph) and at a relatively high angle of attack corresponding to about 67 mph; the effect of size with constant wing loading; three airplanes powered and loaded in the ratio of 1:2:4 but identical in size, appearance and weight distribution; effect of holding the ratio between the static pitching-moment and damping-moment coefficients constant while changing their magnitude. Journal of the Aeronautical Sciences, March 1936, page 158.

High Altitude Problems. M. E. Gluhareff. Power-plant, passenger-comfort, structural, and aerodynamic problems to be solved before high-altitude flying becomes practical for commercial airplanes. In regard to aerodynamic problems, results of a study of six hypothetical airplanes of the same gross weight of 40,000 pounds are given. The author concludes that there is not sufficient assurance today that commercial stratosphere airplanes can be built and operated successfully. Journal of the Aeronautical Sciences, March 1936, page 154.

Model Experiments on Flutter at the Massachusetts Institute of Technology. M. Rauscher. Model experiments to determine empirically the effects of various factors on flutter. General dependence of the critical flutter speed on the angle of attack, and the effects of flexural stiffness, mass and c. g. location, as well as of natural frequency ratio on flexural-torsional flutter are illustrated. Journal of the Aeronautical Sciences, March 1936, page 171.

Some Notes on Aircraft Possibilities. F. S. Barnwell. Possible speeds for monoplanes of the internally-braced rigid-skin type, with special attention to the flying wing are considered in a detailed discussion. Advantages of high wing loading, low power loading and high altitude, stabilizing the flying wing, and adapting it to normal transport purposes, effects of the position of the propellers, practical skin surfaces, and structural and power-plant weights, are discussed. The different lines pointed out, along which improvement might be effected, include turbulence and interference, skin friction, cooling drag, weight, thermal efficiency and propellers. Journal of the Royal Aeronautical Society, March 1936, page 198.

Space Rocket Aircraft with "Dual Personality" Invented. The aircraft described would change its shape from a conventional airplane at lower altitudes to a streamlined roaring rocket ship when the rarefied stratosphere is reached. Discussion of aircraft recently patented by Professor R. H. Goddard. Science News Letter, March 21, 1936, page 183.

Stability and Control Research. Outstanding developments, H. L. Dryden. Two-control operation, A. Klemin. Problems studied at the N.A.C.A., F. E. Weick. Abstracts. Journal of the Aeronautical Sciences, March 1936, page 174.

That Elusive "Ultra-Light" Ideal. W. Boddy. Representative types of the pre-1926 "ultra-light" airplane era compared with the present types, and the author's ideal in regard to weight and speed for a light airplane. Flight, April 9, 1935, page 378a.

Engine-Driven Rotors for the Rapid, Economical and Safe Airplanes of Tomorrow. M. Lame. Aerodynamic principles involved in the Breguet-Dorand gyroplane with two engine-driven rotors, and suggestions for increasing the speed and efficiency of the lifting surfaces. A reduction gear designed by the author for the engine rotor group is illustrated as well as the parts of the engine drive for the Breguet rotor. L'Aeronautique, February 1936, pages 27 and 28.

Full-Scale Tests on the Longitudinal Control of a Low-Wing Monoplane with Special Reference to Wing Wake. J. E. Serby and R. P. Alston. Flight measurement and visual observation of phenomena as manifested at the wing root and at the tail plane of an airplane said to behave curiously in tight turns and loops. Abstract of British Aeronautical Research Committee Reports and Memoranda No. 1666. Aircraft Engineering, April 1936, page 115.

Why the Asboth Helicopter Descends Like a Parachute. M. Victor. Characteristics of the de Asboth rotor which in free rotation permits the helicopter to hover, maneuver and land with the engine off. Wind-tunnel test results given and discussed and design compared with the Pitcairn autogiro. Les Ailes, March 26, 1936, page 5.

Longitudinal Control. A. G. B. Metcalf. Demerits of the present system of longitudinal control of airplanes with suggestions for improvement. An editorial note following lists six points given by the American author as debatable, or not in accordance with British views. Aircraft Engineering, April 1936, page 109.

Modern Racing Aircraft. H. F. King. High-speed planes which have distinguished themselves in speed events in various parts of the world during recent years and the effect of racing on design. General discussion only with brief reference to a few examples of racing planes. Flight, April 9, 1936, page 370.

Retractable Undercarriages. G. H. Dowty. Design requirements for retractable landing gear, classification of retracting mechanisms, methods of operation, emergency lowering mechanisms, safety locks, position indicators, and tail-wheel retraction are discussed. Applications of the various types of retractable landing gear to American and British planes are described and illustrated, among them the Air Corps retraction gear. Discussion following presentation of the paper is also given. Journal Royal Aeronautical Society, April 1936, page 249.

Skin Drag of High Speed Aircraft. S. Hoerner. Laws for the drag of smooth and rough flat surfaces applied to the approximate determination of the minimum possible drag of aerodynamically high-grade aircraft. Translated from Luftfahrtforschung, October 3, 1935. Symbols and units have been translated in accordance with English practice, the graphs redrawn to conform, and the methods applied to the English D H Comet, besides application to the Douglas D C 2 and Heinkel 70 as given in the original article. Aircraft Engineering, April 1936, page 103.

Transport Airplanes. M. Lenoir. Effectiveness and quality of transport planes are developed in formulas with a comparison of the various types and airplanes are compared with other modes of transport. The Dewoitine D. 620, Caudron-Renault C. 640 Typhon, Breguet-Wibault 670, Dewoitine 332, Heinkel He 70, Farman F 224, Douglas DC 2 Bloch 300 Potez 62, DeHavilland DH 86, Heinkel He 111, Kinner, Lockheed, Burnelli UB-14, and Grow planes are briefly described and illustrated. L'Aerophile, February 1936, page 26.

Airplanes

A Pair of Heavyweights. Bomber-transport monoplanes by Caudron-Renault and Dornier. The Caudron-Renault R570 is a twin-engined cantilever monoplane with retractable undercarriage, designed for use as a bomber, troop carrier, freight transport, or ambulance plane. The Dornier high-wing semi-cantilever twin-engined fixed-undercarriage plane is now used extensively by the German air force. Design and performance of both planes described. Flight, March 12, 1936, page 284.

Military Material. Boeing 299 and Focke-Wulf 58. Announced performance of the Boeing, and construction, characteristics and performance of the Focke-Wulf training and bomber planes are given. Brief. L'Aerophile, February 1936, page 37.

Pardonable Pride. The Hawker fighter monoplane does well over 300 mph. and a second fighter, patently the new Supermarine, is expected to reach the same speed. Brief reference with statements that a whole batch of fighters has been turned down by the U. S. Army Air Corps because the performance did not show sufficient improvement over that attained by standard types and that the Air Corps has the fastest type of two-seater fighter. Flight, March 26, 1936, page 319.

BELGIUM

The LACAB Military G R-8 Sesquiplane. The Belgian light multiplace fighter described for scouting and bombardment, is equipped with two Gnome Rhone K-14 780 hp. engines and has a top speed of 360 km. per hour at 4,000 meters. Les Ailes, March 19, 1936, page 3.

FRANCE

Aircraft for the French Navy. Four flying boats are to be developed from the design of the Croix du Sud of the Air France transatlantic service. They will be capable of remaining in the air for 30 hours, will have a cruising speed of 160 mph. and will be employed for long-distance reconnaissance work. Brief reference only. Engineering, April 10, 1936, page 397.

The Caudron-Renault 570 Airplane for Freight Transport. A. Frachet. The airplane described is designed for the transport of troops and materials but may be transformed into an ambulance plane or bomber. With two Renault 18-Jbr 700 hp. engines its speed is 270 km. per hour. Les Ailes, March 26, 1936, page 3.

Caudron C-440 Light Commercial Monoplane. The Caudron-Renault Goeland pllane described has a top speed of 290 km. per hour and is powered by two 180/220-hp. Renault engines. Rivista Aeronautica, February 1936, page 237.

Caudron C-640 "Typhon." The swift single-seater low-wing mail plane described is powered by two Renault 220-hp. engines, and has a top speed of 369 km. per hour and a range of 5100 km. Rivista Aeronautica, February 1936, page 239.

Farman F-224 Commercial Monoplane. The 40-passenger monoplane for Air France has a top speed of 310 km. per hour, and is powered by four 800-hp. engines. Description with three illustrations, one showing cabin layout. Rivista Aeronautica, February 1936, page 235.

Loire 21 Pursuit Seaplane. The single-seater low-wing pursuit ship described was especially designed for launching from a catapult. It climbs 3500 meters in 6 minutes, has a top speed of 310 km. per hour at 3500 meters, and is powered with a 720-hp. Hispano-Suiza 9-Vbs engine. Design described and armament referred to. Rivista Aeronautica, February 1936, page 233.

A Slotted Duck. Claude Canard single-seater flying slotted wing of low aspect ratio. The forward wing, or slat of the slot, is coupled differentially with flaps on the trailing edge of the main wing. Brief description. Aeroplane, March 18, 1936, page 347.

The Latecoere 610. The Latecoere 610 has four Hispano Suiza 14 Ha engines arranged at the leading edge of the wing and should attain 350 km. per hour. A two-engined swift land bomber with a speed of 400 km. per hour is in the course of construction. Brief references only. Les Ailes, March 12, 1936, page 5.

Novel Airplane of Andre Jacquemin. A movable wing automatically controlled an elastic arrangement is one of the features of the new type of small airplane described. Specifications and performance demonstrated in tests are discussed. Les Ailes, March 19, 1936, page 13.

The Performances of the Breguet 27-3 With an Hispano-Suiza 12 Ydrs Engine. Layout of this Breguet with the armament is illustrated, and a table included giving the performances attained both as a bomber and as a long-range scouting plane. Revue de l'Armee de l'Air, February 1936, page 233.

Potez "453 Pursuit Flying Boat." The Potez two-seater pursuit flying boat described is constructed of wood and has a new Hispano-Suiza 14-Hbs 670-750 hp. engine and top speed of 335 km. per hour at 3500 meters. Les Ailes, March 12, 1936, page 3.

The Tests of the "Pou" at Villacoublay. Results of official tests. Les Ailes, March 26, 1936, page 12.

GERMANY

The Dornier Do18 Commercial Flying Boat. The sesquiplane flying boat described is especially designed for catapulting and landing on the sea in the transportation of mail and express on the transatlantic service. The two 500-to 560-hp. Diesel Jumo 205 engines are mounted in tandem above the wing. The plane has a range of 4,450 km. and a top speed of 250 km. per hour. Rivista Aeronautica, February 1936, page 241.

Air and Water. Two four-engined deHavilland 1600-hp. monoplanes have been ordered by the Air Ministry for experimental transatlantic flights. Brief reference. Engineer, March 20, 1936, page 313.

The Empire Flying Boats. Cabin layout and radio equipment of the new Short Empire flying boats with sleeping berths, being built for Imperial Airways. Engineer, April 3, 1936, page 362.

The Airspeed Envoy Series II. Fully-flapped airplane with hydraulically-operated split trailing-edge flaps of Schrenk pattern which extend from aileron to aileron. Landing run of the fully-loaded Envoy in calm air is reduced from 450 yards to less than 150 yards without brakes, and to 70 yards with effective hydraulic brakes. Flight performance, and airstream deflection during and after take-off are explained. Aeroplane, March 18, 1936, page 361. Flight, March 19, 1936, page 300.

An Amateur's "Twininitiation." Flight performance of the new DH twin-engined Dragonfly with specifications and diagram of the cabin layout. Flight, March 19, 1936, page 311.

Portugal Buys British. The Blackburn Shark Float-planes, six of which were purchased for the Portuguese Naval Air Service, are described with five photographs of the plane and two of the Vickers-Berthier 0.303 high-speed gun. Aeroplane, March 11, 1935, page 324. Flight, March 12, 1935, page 282.

Posterity Shall Hear of these Battles. First of the new high-performance medium bombers, the Fairey Battle is said to be the world's fastest bomber. Long well-illustrated description. The stressed-skin construction, unusual operating gear of the retractable undercarriage, and the engine are referred to. Little is given in regard to military features, but the crew is said to be located so that they have an excellent view. The pilot is almost over the leading edge, and the gunner is in line with the trailing edge of the wing roots. Flight, March 26, 1936, page 320.

"Square-Tipped." Impressions of the 1936 Hornet Moth with particular regard to landing. Flight, March 12, 1936, page 291.

Five Monospars. The Monospar ST 25 DeLuxe is one of five new airplane models of the General Aircraft Company developed from the five-seater twin-engined Monospar. Description with particular reference to specialized standard equipment, trimming tabs for new models, and flight performance. Flight, April 2, 1936, page 344.

For Open-Sea Reconnaissance. Structural features of the Saunders-Roe Saro London general-purpose military twin-engined flying boat which is said to have been designed for robustness, low-maintenance cost, simplicity of construction, and seaworthiness. Gunner stations are described and illustrated as well as provisions for living on board. The ship is fitted with two Bristol Pegasus II engines and at the cruising speed of 115 mph. has a range of 1100 miles, the top speed at 6,560 feet being 135 mph. Flight, March 26, 1935, page 332.

A Future British Flying Boat. Sikorsky S 42-A to be built in England by the British Marine Aircraft, Ltd. Specifications are given and layout and parts of particular interest are described and illustrated. Aeroplane, April 1, 1936, page 409.

Our New Raider. Trial flights of the new Fairey Battle two-seater medium bomber airplanes, and some details of the design are described with many illustrations of the plane, as well as a view of the engine and retractable landing year. The plane is powered with a 12-cylinder Rolls Royce Merlin engine and in news items has been credited with a speed of over 300 mph. Aeroplane, March 25, 1936, page 381.

HOLLAND

Fokker D-21 Single-Seater Pursuit Ship. Powered with a Bristol Mercury VI-S the D-21 exceeds 400 km. per hour, but with an Hispano-Suiza 12 Ydrs its theoretical speed is higher than 450 km. per hour. Photograph of plane in its first test flight. Les Ailes, March 12, 1936, page 14.

ITALY

The Caproni "C.H.-1" Pursuit Ship. The Italian pursuit biplane described is said to give the pilot perfect visibility. With a Gnome-Rhone 14 Kfs engine developing 780-hp. at 4,750 m., it has a top speed of 440 km. per hour and cruising speed of 380 km. per hour at that altitude. Long description. Les Ailes, March 5, 1936, page 3.

The Savoia-Marchetti S-84 Commercial Transport. A new Italian twin-engined 18-passenger commercial plane. Specifications and performance only. Les Ailes, March 26, 1936, page 4.

JUGO-SLAVIA

A New Formula. New MMS-3 three-seater produced by Aeroput, Jugo-slavian National Air Line Company. Top speed with two 90-hp. Pobjoy Niagaras is 146 mph. Specifications given. Aeroplane, April 1, 1936, page 416.

POLAND

The Gliding Season of 1935 in Poland. Short outline of attainments with illustrations of the SG3 and CW5 gliders. L'Aerophile, February 1936, page 34.

U. S. A.

Military Airplanes. Twenty-six American military airplanes available for export. Brief illustrated descriptions. Aero Digest, April 1936, page 102.

Private and Commercial Aircraft. Descriptive technical digest of 89 basic American models with data on variation of several types. Aero Digest, April 1936, page 42.

Airplanes for 1936. Illustrated descriptions of all aircraft commercially obtainable in America are given for each plane separately, as well as a four-page table of specifications. Aviation, March 1936, page 21.

Coupe for Private Flying. Curtiss-Wright 2-seater all-metal coupe recently delivered to the Bureau of Air Commerce has a top speed of 131 mph. and is powered with a 90 hp. Lambert engine. Brief description. Scientific American, April 1936, page 203.

Lambert. Twin Monocoach monoplane being completed by Lambert Aircraft Corporation will have an estimated top speed of 160 mph. Few details given. Western Flying, March 1936, page 26.

New Developments at the Air Show. J. G. Thompson. Trends in aircraft progress as indicated by the exhibits at the recent National Pacific Aircraft and Boat Show. Western Flying, March 1936, page 14.

A New Ford-Motored Pusher Plane. The Campbell two-passenger pusher mid-wing monoplane described is powered with a Ford V-8 engine with very little conversion, and is equipped with some of the safety principles developed by Fred Weick. The plane is all-metal with an unusual type of wing structure. Western Flying, March 1936, page 22.

The New Lockheed 12. New 8-plane twin-engined air liner smaller than the Electra is described. Western Flying, March 1936, page 13.

Vultee's New Military Plane. Vultee Model V-11 attack bomber. Performance, armament, and design details given. Western Flying, March 1936, page 25.

U. S. S. R.

Soviets Building Stratosphere Glider for Release from an Altitude of over 12 Miles. Instead of the usual spherical gondola, a glider will be attached to a special frame in the lower part of the gas envelope of a balloon used in past stratosphere ascents. The hermetically sealed cabin will hold two persons. At an altitude of 12.5 miles, a lever will release the glider and start it into a nose dive. The purpose of the glider is to obtain data on the phenomena of a falling body in the stratosphere. Brief reference. Bulletin of the American Meteorological Society, March 1936, page 92.

Airships

The Electrical Installations of the LZ-129. E. Hilligardt. Generating plant and distribution system, lighting system, beacons, combined manual and electrically driven control for tail surfaces, electric kitchen equipment, heating system, ventilation, and electric pump for water supply are discussed. Navigation equipment is also described including the long- and short-wave radio transmitters and receivers, sonic altimeter, gyro compass, rpm and speed indicators, ballast and gas control, temperature measurements and telephone installation. Twelve-page description with many illustrations and diagrams of installations. Elektrotechnische Zeitschrift, March 26, 1936, page 354.

World's Largest Airship Will Visit Us in May. Specifications and brief description of the LZ-129 as well as the text of the proposed law to promote the development of lighter-than-air craft in the United States. U. S. Air Services, April 1936, page 15.

The Zeppelin Airship LZ-129. Dimensions and form, new arrangement of passenger cabins in the ship's body, girder construction, rings, catwalk and connecting walk, tail surfaces, hull, gas bags, gas shaft, engine and propeller installations, electric power plant, pilot gondola, rudder installation, radio, engineer's room, storage room are described and fire extinguishers and rescue apparatus are referred to. Fourteen page description with fifty photographs and diagrams. V.D.I., March 28, 1936, page 379.

The New Zeppelin. Semi-technical aspects of the LZ-129, the first test flights, the alternative fuel-gas system, and features of the metal structure are described. Flight, March 12, 1936, page 284-a. Two trial flights briefly described. Engineer, March 13, 1936, page 275.

Metals

ASTM Reviews Constructional Metals. High-strength constructional metals were the subject of a recent ASTM five-paper symposium, as follows:—"Alloys of Aluminum and Magnesium," J. I. Bowman and E. H. Dix, Jr.: "Alloys of Copper," C. H. Davis; "Alloys of Nickel," G. F. Geiger; "Carbon and Low-Alloy Steels," E. F. Cone; "Corrosion-Resisting Steels" by E. E. Thum. Abstracts. Iron Age, March 12, 1936, page 55.

Tubing in Aircraft. A. E. Reynolds. Manufacture and uses of steel, aluminum and magnesium alloy tubes for aircraft. Applications of special forms of steel and aluminum alloy tube, which are found in recent designs are illustrated and processes described. Flight Aircraft Engineer Supplement, March 26, 1936, page 20.

Design Aspect of Creep. R. W. Bailey. Factors concerned in the development of a rational treatment of creep of metals for the purpose of engineering design. The abstract covers:—general expressions for creep; influence of temperature on creep constants; applications to problems in the design of hollow cylinders subjected to internal pressures, of steam piping, and of rotating disks; determination of creep properties for design; relation between creep rates; and the failure of low-alloy high-creep-resistant steels. Abstracted from papers presented before the ASME and Institution of Mechanical Engineers. Journal of Applied Mechanics, ASME Transactions, March 1936, page A-1.

CORROSION AND PROTECTIVE COATINGS

Metal Coatings for Aircraft Structures. R. M. Wick. Cuprous-oxide rectifiers are widely used in England to convert alternating into direct current for electrodeposition. Review of foreign practice in metal coating observed during a visit to study foreign practice in metal protection for aircraft. Problem of protecting magnesium parts against corrosion, fatigue tests on actual parts at the DVL, and the Schwartz process for producing wood propellers used on British and German military aircraft are discussed. Abstract of paper presented before The Aircrafters. Automotive Industries, March 21, 1936, page 423.

WELDING

Welding in Aviation. C. de Ganahl. Oxyacetylene welding of chrome-molybdenum steel, difficulties in electric-resistance welding of this steel, and its corrosion protection are briefly reviewed. Shot welding high-tensile stainless steel and torch welding titanium—and columbium-bearing steel are also taken up. Exhaust manifolds of 18-8 stainless steel containing titanium or columbium are referred to as standard practice with the Army Air Corps and Navy. Welding Journal, March 1936, page 8.

Welding in Aircraft Structures. R. H. Dobson and R. F. Taylor. Possibilities of electrical-resistance seam and spot welding in stressed-skin aircraft structures. Test results obtained with Alclad to specification D T D 118 and improvements in similar materials welded by means of remote electrodes and mercury-valve grid-controlled equipment are referred to. Abstract of paper presented before the Royal Aeronautical Society. Flight, April 2, 1936, page 353. Longer abstract with illustrations of a hull and float being welded by means of a Sciaky welding machine. Aeroplane, April 1, 1936, page 415.

Non-Metallic Materials

PLASTICS

Acrylic Resins. H. T. Neher. Historical basis, industrial development, homologs of the acrylates, polymorization and polymoric forms, properties, and uses of acrylic resins are covered. An acryloid hood for a passenger plane is illustrated. Industrial and Engineering Chemistry, Industrial Edition, March 1936, page 267.

Plastics for Bodies. E. F. Lorgee. Clear transparent material taking the place of glass in certain places is now being used on airships and omnibus windows in Europe, according to the very brief reference given in connection with the prediction that plastic panels would replace fabrics for the interior trim of automobiles. Automotive Industries, March 21, 1936, page 421.

A Remarkable Plastic. Tufnol is said to be half the weight of aluminum but equal to it in tensile strength, to be unaffected by climatic conditions, and not to expand or contract from heat or cold. Properties and applications in aircraft construction are briefly discussed. Flight, March 19, 1936, page 304.

Safety Glass Made from New Plastic. Greater strength at low temperatures and higher shock resistance are claimed for the new high-strength safety glass developed by the Pittsburgh Plate Glass Company. Development of Vinal, a new plastic of unusual elastic and tensile properties, is said to have overcome certain limitations of the earlier types of safety glass. Composition and properties of Vinal are briefly discussed. Automobile Industries, March 21, 1936, page 425.

Transparent Thermoplastics. Perspex and Diakon, two new transparent resins are rapidly gaining favor with British aircraft designers for windows, inspection doors, and gun turrets. Perspex has been approved for all production types of military and civil aircraft. Very brief discussion of properties and applications. Flight Aircraft Engineer Supplement, March 26, 1936, page 19.

Stress Analysis and Structures

Charts for the Determination of Elastic Stability of Planar Compression Member Groups. K. Borkmann. Exact determination of compressive strength of certain built-up or composite columns. Very brief abstract from Luftfahrforschung, January 20, 1936. Aero Digest, April 1936, page 32.

A Distribution Method of Stress Analysis. J. F. Baker and A. J. Ocklestone. Advantages of the Cross method of analysis. Abstract of British Aeronautical Research Committee Reports and Memoranda No. 1667. Mechanical Engineering, April 1936, page 247.

Formulas of the Three Moments. Three-moment equations are developed for calculating the excessive reactions. Les Ailes, March 19, 1936, page 5.

Notes on the Strength of Stressed Skin Fuselages. G. F. Wallace. Shear strength of the panels, the compression strength of thin panels, and bending and shear stresses in the transverse rings or frames under various systems of external loads. Methods of calculation are taken from N. A. C. A. reports and other sources. Journal Royal Aeronautical Society, April 1936, page 304.

Compound Metal Sheets and Their Applications to Aeronautical Construction. R. V. Le Ricolais. A combination of flat and corrugated metal sheets, called "Isoflex," is applied to airplane wing structures and covering. Successive operations in the fabrication of a box spar of Isoflex construction are illustrated. The construction is said to be similar to that used on the Martin B10 bomber and Martin China Clipper. L'Aeronautique, February 1936, page 25.

Design for a Plastics Wing. S. Ireland. Practicability of constructing a wing out of existing plastic materials is discussed in detail. The author believes this to be economically possible and indicates what should be the fruitful lines of development to the plastics industry. A trial design of a wing is described which uses materials available at present as a basis for design, and a stress analysis is made. Methods developed for reinforced concrete design are applied and the tension flange is reinforced by inserting the correct percentage of steel wire reinforcement. Aeroplane, Aeronautical Engineering Supplement, March 18, 1936, page 345.

Stress and Deflection of Circular Plates. A. M. Wahl and S. Way. Formulas for the calculation of engineering structures having the shape of flat circular plates of uniform thickness with various loading and edge conditions. Journal of Applied Mechanics, A.S.M.E. Transactions, March 1936, page A-28.

Structural Problems. J. S. Newell. The major aircraft structural problems briefly reviewed cover an interpretation of aerodynamic data and its application to requirements for structural airworthiness, high-altitude flight requirements, and the determination of the effect of "shear-lag" on built-up sections of wings and fuselages. Journal of the Aeronautical Sciences, March 1936, page 180.

Two- and Three-Dimensional Cases of Stress Concentration, and Comparison with Fatigue Tests. R. E. Peterson and A. M. Wahl. Study of some two- and three-dimensional cases of stress distribution with particular reference to shafts having fillets or transverse holes. Journal of Applied Mechanics, A.S.M.E. Transactions, March 1936, page A-15.

Methods of Joining Materials Used in Strong, Light Structures. R. H. Hobrock. Experiments on wing spars for airplanes are reviewed with a description of how the loading was obtained and how the spars behaved under the load. Two-page abstract of Daniel Guggenheim Airship Institute Publication No. 3, 1935. Mechanical Engineering, April 1936, page 250.

Shear Stresses in Hollow Sections. W. J. Goodey. Theory of stresses in bending and torsion for designers of stresses-skin structures for aircraft. Formulas are derived for finding shear stress distribution in a beam of hollow section with internal partitions when subjected to bending, and shear stress distribution due to torque. Aircraft Engineering, April 1936, page 93.

The Stressing of Monoplane Wings. H. N. Horne. A rapid graphical method of treating a two-spar wing with stiff covering and parallel or non-parallel spars. Flight, Aircraft Engineer Supplement, March 26, 1936, page 17.

Engine Design and Research

In Search of Silence. Aircraft-engine silencing experiments at the Royal Aircraft Establishment and a review of modern proprietary silencers. Exhaust noise, said to be the chief problem at cruising speeds, is analyzed and results of tests are given. An R. A. E. silencer, the latest Vokes venturi-type silencer for the Rolls-Royce Kestrel, as well as the Vokes silencers for the Gnome-Rhone Mistral Major and the D. H. Gipsey Six engines, the Burgess HDF type of silencer, and the Bristol single-outlet exhaust collector ring are described. Flight, March 12, 1936, page 272.

Spring Surge Investigated. W. Marti. Vibrational characteristics of valve springs were investigated by both analytic and experimental methods. Results obtained and apparatus used are discussed. Translated abstract of thesis presented to the Federal Technical College of Zurich for the degree of Doctor of Technical Science. Automotive Industries, March 14, 1936, page 411.

Aircraft Engine Sessions. "Fuel Economy: the Operator's Viewpoint," E. T. Allen. "Air-Cooled Radial Engine Performance Possibilities and Means for Obtaining Optimum Fuel Economy in Flight," R. W. Young. "Eliminating Crankshaft Torsional Vibration in Radial Aircraft Engines," E. S. Taylor. "Rating Aviation Fuels in Full-Scale Aircraft Engines—Report of Cooperative Fuel Research Committee," C. B. Veal. "Carburetor Icing in Airline Operation," W. A. Hamilton. Abstract of Annual Meeting papers. S. A. E. Journal, February 1936, page 39.

Cylinder Wear Sessions. "Cylinder Wear, Where and Why," S. W. Sparrow and T. A. Schlerger. "Cylinder Wear in Diesel Engines," G. D. Boerlage and B. J. Gravesteyn. "Cylinder Wear in Gasoline Engines," C. G. Williams. "Aircraft Engine Piston-Ring and Cylinder Wear," R. Insley. "Cylinder Wear and Piston-Ring Sticking Tendencies of Automobile, Bus and Aircraft Engines," C. M. Larson, W. G. Ainsley and M. Fairlie. "Effect of Gas Pressure on Piston Friction," M. P. Taylor. Brief abstracts of Annual Meeting papers. S. A. E. Journal, February 1936, page 36.

Cylinder Wear, Where and Why. S. W. Sparrow and T. A. Schlerger. Inadequate lubrication, but not necessarily insufficient lubricant, was found to be the primary cause of cylinder wear in the experiments discussed. Numerous charts are given to show the wear of cylinder and piston rings. The fact that maximum wear is usually found in line with the top ring at the upper limit of its travel is attributed to the presence of dirt and to the high temperatures which make lubrication difficult in this region. Special experiments described illustrate the effects of insufficient oil, of abrasives, of rough surfaces, and of high local temperatures. S. A. E. Journal (Transactions), April 1936, page 117.

Describes Developments in Airplane Engines. E. H. Hamilton. In the original paper the author is said to describe fuel-injection systems for gasoline engines, such as now used by the Military Service. The power-plant of the future is predicted as a large compression-ignition engine completely enclosed in the wing with an evaporative cooling system. Brief abstract only. S. A. E. Journal, April 1936, page 25.

Engine Nacelles and Propellers and Airplane Performance. D. H. Wood. Extensive N. A. C. A. experimental study of engine-nacelle location and cowling, including engines mounted entirely within the wing with propeller driven through an extension shaft. Effect of engine size on nacelle drag is discussed and charts give values which may be used in calculating the nacelle drag in preliminary performance estimates. A reduction of radiator drag for liquid-cooled engines to less than half the present values is believed possible. S. A. E. Journal (Transactions), April 1936, page 148.

Engine Roughness—Its Cause and Cure. P. M. Heldt. Roughness in engine operation is said to consist of synchronous transverse vibration of the crankcase, due to variations in gas pressure and inertia. The author believes the best safeguard against trouble from rough operation is to design the crankcase so that it is quite stiff in both the horizontal and vertical planes. S. A. E. Journal (Transactions), February 1936, page 47.

Fuels and Lubricants and Passenger Car Session. "The Relation of Exhaust-Gas Composition to Air-Fuel Ratio," B. A. D'Alleva and W. G. Lovell. "Thermodynamics of Volume Distribution," R. L. Sweigert. Abstract of Annual Meeting papers. S. A. E. Journal, February 1936, page 39.

Influence of Atmospheric Conditions on the Power of Explosion Engines. M. Serruys and T. Te-Lou. Corrections applicable to the power of aircraft engines under varying atmospheric conditions. Results of tests are only given in the original report but charts illustrated in the article show the effect of atmospheric pressure, humidity, and outside temperature on engine power. Abstract from Publication Scientifiques et Techniques du Ministere de l'Air No. 77. Aero Digest, April 1936, page 32.

Manufacture of Pinions in Couples for Reduction Gears in Russia. M. Precoul. Design of the reduction gear for the Russian M-34 750-hp. engine and methods of producing it. L'Aerophile, February 1936, page 41.

Resonance Between Engine and Propeller. Efforts of the Material Division of the Army Air Corps to reduce torsional vibration in radial engines are described with the statement that European engines and propellers are not subject to these phenomena. Les Ailes, March 19, 1936, page 5.

An Unusual Two-Stroke Engine. One or two Zoller compressors are employed to supply mixtures through the piston-operated inlet ports in the walls of each cylinder of the unusual engine described. In order to induce turbulence the ports are formed like a series of turbine blades. Novel features of the rotary valves are described in detail. The design was developed by Cuddon-Fletcher and is in the process of experimental manufacture for aircraft and other engines. In the 16-cylinder aircraft engine proposed, a dry weight of less than 1 lb. per hp. is hoped for. Flight, March 26, 1936, page 338.

Accessories

Better Lubrication by Centrifugal Action. The centrifugal separator described is used on the new Wright Whirlwind and in the lubricating system before the oil passes to the master-rod bearings. Brief description. Scientific American, April 1936, page 201.

Positive Displacement Vane-Type Blower. Advantages of high volumetric displacement for given over-all dimensions and a minimum number of parts subjected to frictional effects are claimed for the new positive-displacement vane-type Kratzer blower developed for supercharging racing cars. Design described and illustrated. Automotive Industries, March 14, 1936, page 408.

Carburetion Practice in Aero Engines. F. C. Stokes. Development of carburetors for special aircraft requirements. History of the development is traced, the first article covering a period beginning with representative types of nineteenth-century automobile-engine carburetors up to 1914. Aircraft Engineering, April 1936, page 96.

Positive Control. Arens system of positive push-pull control used mostly on aircraft for the operation of throttles, mixture controls, gasoline cocks, orientable landing lights and variable-pitch propellers. Brief illustrated description. Flight, April 9, 1936, page 387.

Diesels

Some Compression-Ignition Engine Problems. G. Amery. The ideal fuel-injection system, the jerk pump system and its functioning, and spontaneous combustion in C. I. engine theory are taken up in the first article. The second deals with air temperature and pressure, velocity of the droplet, and the coefficients of friction and of contact for each fuel, and coefficients of thermal conductivity for each fuel from section to section of the fuel, and from skin to mass. Engineer, March 20 and 27, 1936, pages 307 and 328.

Tests with Gasoline Injection and Spark-Plug Ignition in a Diesel Motor. P. Langer and H. Vuellers. Conclusions reached in a test on a six-cylinder precombustion-chamber 7.07-liter Diesel engine. Abstracted from Automobiltechnische Zeitschrift, October 10, 1935, page 471. Mechanical Engineering, April 1936, page 248.

Heavy Oil Engines

Fuel-Oil Spark-Ignition Engine Developed in Finland. H. A. Branders. The Ares fuel vaporizer described was tested in aviation engines and gave excellent results with a Cirrus engine operating on fuel oil. The vaporizer consists of a ring provided with helical baffles, which imparts a swirling motion to the air during the suction and compression strokes, and also functions as a heat-storage member. An 8-cylinder 520-hp. and a smaller 6-cylinder 180-hp. engine using this vaporizer are also discussed. Automotive Industries, March 21, 1936, page 445.

Light-Alloy Piston for Diesel Engines. The light-alloy composite piston described was developed for Diesel engines in which the fuel spray is likely to strike the piston head and cause cracking in time. Body of the piston is made of silicon-aluminum alloy and the top central portion of the head of Y alloy. Brief translation abstracted from A. T. Z., December 1935. Automotive Industries, March 14, 1936, page 412.

Engines

American Aircraft Engines. Specifications, construction, and illustrations of 52 American aircraft engines. Aero Digest, April 1936, pages 41 and 122.

A Brief Survey of American Engines for 1936. G. D Angle. Progress in engineering, existing trends in design as to selection of types, and growth of the industry as determined from the number of manufacturers, engine types, and models. Aero Digest, April 1936, page 28.

Engines for 1936. Aircraft engines now commercially obtainable in America. Illustrated descriptions for each engine and a two-page table specification. Aviation, March 1936, page 88.

Progress in Aviation Engine Development. Definite trend toward in-line inverted engines of four and six cylinders in the lower power range while the high-horsepower field seems to be swinging towards the two-row radial. Nearly half of the airplanes on display were powered with linear engines. Trends indicated by the exhibits at the recent National Pacific Aircraft and Boat Show. Western Flying, March 1936, page 17.

The "Hindenburg's" New Diesels. The Mercedes-Benz LOF-6 16-cylinder Vee-type Diesel engines of the LZ-129 airship, and their development for airship purposes are described. The maximum power of each of the four engines is 1200 hp. while the long-period power is 800 to 90 hp. Flight, March 26, 1936, page 339.

Power for the Empire Boats. A controllable-flap cowling to afford control of cooling is a feature of the Bristol Pegasus X.c. 9-cylinder radial aircraft engine described. For a weight of 1000 lb. 920 hp. is developed. New cylinder heads and pistons are described. Flight, April 9, 1936, page 384.

Propulsion Installation of the LZ-129 Zeppelin Airship. F. Sturm. Daimler-Benz 800 to 900-hp. Diesel engines. Exhaust arrangement, supervision and installation of fuel and oil, and engine vibration conditions are discussed with eleven photographs, diagrams and engine-vibration and performance curves. V. D. I., March 28, 1936, page 393.

Technical Notes. New series 12-Y Hispano-Suiza engine has a compression ratio of 7 instead of 5.8, and develops 800 hp. on the ground and 860 to 920 hp. at altitude of 3,100 to 3,600 meters. Brief reference only. Les Ailes, March 19, 1936, page 5.

Technical Notes. Schliha flat-twin opposed-cylinder two-cycle engine described develops a maximum of 36 hp. at 3100 r.p.m. Brief description. Les Ailes, March 19, 1936, page 5.

Engine Testing

Bench Testing of Engines. C. O. B. Beale. Calculation of the dimensions of an engine from those of the inlet valve as a base and an examination of parts controlling performance before beginning the tests are recommended with a table of relative inlet velocities in feet per second at peak torque speeds. The author is a member of the experimental staff of Ricardo and Company. Brief abstract from I. E. A. Journal, February 1936. Automotive Industries, April 18, 1936, page 575.

Measurement of Gas Temperatures in an Internal Combustion Engine. A. E. Hershey. Measurement by means of the radiation and spectral-line-reversal methods described was developed in a study made at the Engineering Experimental Station of the University of Illinois. Other methods of determining gas temperatures in an engine during the combustion and expansion periods are evaluated. Transactions A. S. M. E., April 1936, page 195.

The New IAE Research Laboratory. Equipment and tests being conducted by the Institution of Automobile Engineers Brief. Engineer, March 27, 1936, page 345.

Does Specific Fuel Consumption Need Correction for Atmospheric Conditions? P. M. Heldt. Specific fuel consumption determined by tests under other than standard conditions of atmospheric density. The application of a correction factor similar to that used to obtain corrected horsepower under standard atmospheric conditions is said to be unnecessary. Automotive Industries, March 21, 1936, page 442.

Engines on the Spot. P. M. Heldt. The cathode-ray oscillograph with a piezo-electric detector or pick-up device was developed by the R. C. A. Manufacturing Company for investigations on engine-cylinder phenomena, vibration and noise. Very detailed description. Automotive Industries, March 14, 1936, page 398.

Universal Test Stand for Measuring Engine Torque. The test stand described, which was developed by Chief Engineer Poincare, Inspector-General Dumanois and C. Waseige, for measuring engine torque, utilizes the reaction exerted on the pinions of a mechanism similar to a planetary reduction gear. Long description with details of altitude tests. Les Ailes, March 5, 1936, page 5.

Rocket Propulsion

Airmail by Rocket? Rocket, recently tried out without success at Greenwood Lake for carrying air mail is briefly described. Scientific American, April 1936, page 202.

Progress in the Development of Atmospheric Sounding Rockets. R. H. Goddard. General plan of rocket development and main objects accomplished during the period 1930–1935. Problems in developing a satisfactory combustion chamber, in keeping the rocket in a vertical course automatically, and in producing a rocket of lighter weight are briefly referred to. Abstract only. Bulletin of the American Meteorological Society, February 1936, page 31.

Rocket Motor Develops 200 Horsepower Per Pound. Speeds as great as 700 m.p.h. are also claimed for the Goddard rocket. This statement and only a very brief comparison with weight per horsepower of the automobile, military-aircraft, and train motors. Reference to research progress report of Professor R. Goddard issued by the Smithsonian Institute. Science News Letter, March 28, 1936, page 201.

Rocket Research Removes Need of Carrying Liquid Oxygen to Burn Fuel. New method for propulsion of rockets in stratospheric flight, developed by A. C. Erickson. Brief abstract from Journal of the Aeronautical Sciences, No. 3, 1935, page 118. Bulletin of the American Meteorological Society, February 1936, page 32.

Fuels and Lubricants

Alcohol Blends. Conflicting claims of chemists at the American Chemical Society meeting regarding the increase in mileage, performance and economy obtained in the use of alcohol blended motor fuels without extensive adjustment of the engine. Automotive Industries, April 18, 1936, page 549.

Diesel Engine and Fuels and Lubricants Session. "Cetane Rating of Diesel Fuels," P. H. Schweitzer. "Report of Volunteer Group for C. I. Fuel Research," T. B. Rendel. "Diesel Fuels—Significance of Ignition Characteristics," J. R. MacGregor. Brief Abstracts of Annual Meeting papers. S. A. E. Journal, February 1936, page 34.

Dissipation of Carburetor Ice. C. C. Callis. Newly developed stabilized alcohol-gasoline fuel which will not "ice" and which will clear a carburetor quickly and effectively of ice accretions that have already formed. Results of tests are quoted to show that the stabilizer does not adversely affect the lead susceptibility of a stabilized fuel. Aero Digest, April 1936, page 26.

Higher Performance with 100 Octane. Air Corps tests with 100-octane fuels. Brief reference. Scientific American, April 1936, page 201.

The Laboratory Engine Testing of Motor Lubricants. M. Fairlie. A liquid-cooled engine with high jacket temperatures was used for the tests described because of the advantages in showing at one time oil oxidation and the effect of the oxidation products with respect to ring sticking, and alloy-bearing corrosion. Engine test set-up and procedure, evaluation of results, and modifications to measure corrosion of alloy bearings are given. Oil and Gas Journal, March 19, 1936, page 114.

Liquefied-Gas Fuels. A. L. Cloyden. Favorable results shown in the commercial use of liquified-gas fuels in gasoline engines. Their use is said to eliminate all troubles in connection with charge distribution, to leave no carbon deposits as well as practically no carbon monoxide in the exhaust, and to reduce mechanical wear in the engine. Results of tests carried out by the Sun Oil Company with a C. F. R. engine and modifications of a White truck engine to use this fuel are briefly referred to. Future of the Diesel and low thermal efficiency of the modern automobile also briefly discussed. Abstract of paper presented before the Philadelphia Section of the S. A. E. Automotive Industries, March 14, 1936, page 388.

Propellers

De-Icing the Propeller. Propeller de-icing system, developed by the Bureau of Air Commerce and T. W. A. in cooperation with the Goodrich Company. Wind-tunnel set-up for studying propeller de-icing is illustrated and briefly described, also. Scientific American, April 1936, page 200.

The Ratier Propeller with Electrically Controlled Pitch. Parts of the new three-bladed electrically-controlled Ratier propeller used on the Latecoere 300 "Croce del Sud" plane are illustrated and described. Rivista Aeronautica, February 1936, page 249.

Variable-Pitch Airscrews. Conclusions reached in Dr. Watt's recent paper before the Royal Aeronautical Society and the Schwarz process for manufacturing propeller blades are discussed in an editorial. Engineering, March 6, 1936, page 263.

The Schwarz Automatic V. P. Airscrew. Extreme simplicity is said to be the feature of the fully automatic two-pitch propeller described, which can be adapted to the "moteur canon." Although used with the Schwartz wooden detachable blades, the hub may be fitted also with metal blades. Flight, April 9, 1936, page 374.

Tables for Use in an Improved Method of Airscrew Strip Theory Calculation. .C. N. H. Lock and D. Yeatman. Airscrew strip theory calculations are extended to the case of four-bladed propellers and to higher pitch values in the original report described here. Abstract of British Aeronautical Research Committee Reports and Memoranda. Aircraft Engineering, April 1936, page 115.

Propeller Crankshaft—Vibration Problems. H. H. Clough. Study of propeller failures and of propeller vibration under operating conditions which was made by the Air Corps. Various types of crankshaft vibration and methods of determining it are explained and a magnetic pick-up used in the study of propeller vibration, and oscillograph propeller-vibration records are described. Methods are proposed for preventing most of the destructive forces from reaching the propeller in the case of the nine-cylinder and fourteen-cylinder geared engines and of the in-line engines with long crankshafts. Mechanical Engineering, April 1936, page 215.

Acoustics

Insulation Material. Dry-Zero Airplane Blanket, fabricated thermal and sound insulating material. Properties and weight of various thicknesses briefly referred to. Aero Digest, April 1936, page 34.

Silence Within. Methods of soundproofing applied to the cabins of modern airplanes and problem to be solved. Position of the engines and propellers in relation to the passenger cabin, the easiest type of cabin to silence, reduction of vibration transmitted from the engine, ventilation, and American and British sound-proofing materials are discussed with references to Seapak, Cellocol, a Sperry process, and Cellon. Decrease of noise level with altitude is also shown. Flight, April 2, 1936, page 348.

Airport Equipment

Airship Stations for Zeppelin Transportation. A. Kolb. Mooring-mast equipment, airship landing fields, and the hydrogen-gas generating installations at Pernambuco, Rio de Janeiro—St. Cruz, Rhein Main and Seville are described. V.D.I., March 28, 1936, page 398.

Automatic Course Indication. The Aga beacon described differs from the normal type in that it is designed to give different combinations of light flashes for observers in different positions relative to the beacon. Flight, March 26, 1936, page 326.

The Drying of Large Flying Boats. Equipment for handling large flying boats on board ship as well as in the hangars. L'Aeronautique, February 1936, page 41.

A Modern Airport Beacon. The spherical GE 36-inch "Bartow" beacon described is almost entirely lens and incorporates three types of beams in one beacon. Scientific American, April 1936, page 201.

Armament

Bomber Versus Pursuit. The new 37-mm. cannon developed by the American Armament Corporation is thought to be the most powerful weapon ever mounted on an aircraft. The gun is mounted in the rear cockpit of the bomber and is capable of 360-degree rotation, 15-degree depression and 60-degree elevation. Very brief description with reference to wind-tunnel tests to balance the gun aerodynamically. Scientific American, April 1936, page 202.

Fire Extinguishers

An Aerodrome Fire Engine. In cases of airplane crash fires with the engine described a large quantity of inert gas can be discharged within three minutes, driving the flames down and producing low temperature by the rapid expansion of a large quantity of gas. There is also a normal water jet or a foam jet for use in ordinary fires in hangars. Engineer, March 13, 1936, page 296.

Two-Stage Fire Extinction. The new Merryweather airport fire engine is equipped with a battery of CO_2 cylinders which can release 4,000 cu. ft. of gas in three minutes thus subduing an aircraft fire in order to allow the occupants to be extricated. After this has been done, the fire is attacked by foam from "Xaust-Suds" apparatus. Photograph with very brief description in caption. Flight, April 2, 1936, page 366.

Instruments

Advances in Aircraft Instruments and Accessories. Autosyn Pioneer remote-indicating instrument, Bendix wheel brakes, Eclipse remote-reading fuel flow meter, Pacific Airmotive Corporation exhibits, Kollsman instruments, Romec fuel pump and other accessories displayed at the recent National Pacific Aircraft and Boat Show are described. Western Flying, March 1936, page 19.

A Convenient Drift and Speed Indicator. The Kollsman instrument described is used by Pan-American Airways in connection with smoke signals during flights over sea. Scientific American, April 1936, page 200.

The Effect of Tubing on the Indications of an Airspeed Meter. W. R. Weems. Pressure changes typical of those occuring in flight were imposed upon the airspeed meter and tubing installation in the MIT investigation described. It is concluded that the connecting tube of an airspeed meter behaves essentially as a capillary, that for ordinary installations of standard 3/16-inch tubing no appreciable error is introduced by the tubing, and that 1/8-inch tubing may be used in most cases. Journal of the Aeronautical Sciences, March 1936, page 165.

Flying in the Clouds. General practice in checking altimeter readings by the use of airport values reduced to sea level according to "standard atmosphere," and the fact that so-called "sea-level" pressures are not sea-level pressures except when the temperature of the air is that of the standard atmosphere. Brief discussion of two errors made in the December Bulletin. Bulletin of the American Meteorological Society, February 1936, page 51.

Something New in Fuel Gauges. New form of contents gauge and flow-meter developed by Short and Mason, Ltd. The contents gauge consists of a bellows system placed at the bottom of the tank and the pressure of air in the bellows is read from a calibrated gauge. The flow-meter unit consists of a double bellows between wnich the fuel flows and increase in flow reduces the static pressure so that the bellows contract. Brief description. Aeroplane, March 11, 1936, page 336. Description and hypothetical layout. Flight, March 19, 1936, page 303.

Airplane Pilots Can Be Warned of Diminished Fuel Supply by New Device. A safety device to warn the pilot of any interruption in the flow of fuel from the tank to the pump. Product of the Steel Products Engineering Company. Description and drawing. Automotive Industries, April 11, 1936, page 536.

The Rousselle Altithermometer. P. Rousselle. Combination of an altimeter and thermometer indicating the state of stability or instability, of the atmosphere in comparison with the adiabatic gradient ot the temperature in dry atmosphere. Les Ailes, March 12, 1936, page 5.

TESTING

The New Instrument Laboratory at the Massachusetts Institute of Technology. C. S. Draper. Fundamental instrument problems are studied by means of the special apparatus described, in order to check the agreement of theoretical predictions with experiment. A model mechanical system which automatically draws response curves for an arbitrary variation of the actuating force, a mechanical vibration apparatus, and a compass analyzer, are described, as well as apparatus for checking humidity, thermometer lag, and gyroscope rotor drive. Journal of the Aeronautical Sciences, March 1936, page 151.

Parachutes

The Parachute. Colonel G. Biffi. Recent parachute maneuvers carried out by the Russian Army are reviewed and the possibilities for such applications of the parachute are discussed with regard to the morphological conditions of the ground in the various sections of Europe. Questions of safety and means of operation are also considered. Rivista Aeronautica, February 1936, page 153.

Photography

An International Necessity. At least two people in England have advanced a very long way in their work on infra-red detectors which may eventually oust the present short-wave approach system. Statement made in brief editorial on the immediate necessity for a rigid standardization of aircraft approach systems. Flight, April 9, 1936, page 367.

Radio

450 Miles Above the Clouds. Flying the Basle-London airline with the aid of the Lorenz ultra-short-wave beam and the Sperry artificial horizon and directional gyro. General description. Aeroplane, March 25, 1936, page 391.

Deviations of Direction Finders on Board Airplanes. E. Fromy. Disturbances affecting direction finders, due to the metallic parts of the airplane, are analyzed and rules are defined for reducing their effects and eventually compensating them. A general formula is established for determining the error in bearing and factors affecting it. L'Onde Electrique, February 1936, page 113.

Landing of Airplanes in Bad Weather. C. A. F. von Gablenz. German practice in instrument flying, radio bearing, training of pilots, landing by means of the ZZ method and by means of short-wave beacons and supervision of all transport planes from the ground are taken up in a general discussion. V.D.I., March 21, 1936, page 347.

Our Inquiry Regarding Radio for Aviation. Answers to questions regarding the type of radio apparatus required for aircraft. Les Ailes, March 12, 1936, page 4.

Radio for the Charter Pilot. Marconi AD 49/50 radio transmitting and receiving set developed for the private owner or small commercial operator weighs 62 pounds when working from either a rotary transformer driven from the 12-volt aircraft lighting equipment, or from a constant-speed wind-driven generator. Brief description. Flight, April 9, 1936, page 383.

Some Radio Applications in Aeronautics. H. Portier. The French radio system for directing aircraft is described and compared with the German Lorenz system, and the ZZ radio landing method is discussed. L'Onde Electrique, January 1936, page 33.

Tune in the Zeppelin. Radio equipment of the LZ 129 very briefly described. Wireless World, March 27, 1936, page 313.

Wireless Equipment for Empire Flying Boats. In the Marconi radio equipment for the new Short flying boats, the direction finder will be combined with the ordinary receiver and generators will be driven by two of the four main airplane engines. The short and medium wavelength transmitter, the motor generator set and gasoline engine for power supply, and the retractable rotating loop aerial for direction finding are described and illustrated. Engineering, April 3, 1936, page 380. Flight, April 2, 1936, page 364.

Low Frequency Transmission over Transatlantic Paths. H. H. Beverage and G. W. Kendrick. Continuous records of field intensity taken at several receiving points and on various types of antenna systems are compared. Evidence of incoherent low-frequency fading is found. Several measures of variability are discussed and changes observed are compared with variations in earth potentials. Abnormally low group velocities for low-frequency transmission are taken up. Proceedings of the Institute of Radio Engineers, March 1936, page 472.

Radio Tube Without Filament Aid to Radio and Television. P. T. Farnsworth. Potentialities in the design of light-weight radio transmitters for aircraft, and in the development of television are claimed for the new type of radio tube without a filament. The tube is of the cold-cathode type and known as the Multipactor. Abstract of paper presented before the Institute of Radio Engineers. Science News Letter, March 21, 1936, page 182.

New Radio Equipment. New pentode valves about double the efficiency with the possibility of working stations at 250 to 300 miles instead of at 150. These valves are incorporated in the transmitters of the two latest sets for aircraft developed by Radio Transmission Equipment, Ltd. The AC 45 comprises combined long-and short-wave transmitter, receiver, and remote control system, while the AC 46 comprises a long-wave transmitter, receiver, and remote control system. Aeroplane, March 18, 1936, page 264.

A Review of Radio Communication in the Mobile Services. C. N. Anderson. Developments in the application of radio to marine, aviation and police fields. Improvements during the year in airway beacons and radio compasses, and trials of airport traffic control and blind landing systems are discussed and a small 5-watt transmitter is referred to which was made available for the use of the itinerant flyer in communicating with airports. Proceedings of the Institute of Radio Engineers, March 1936, page 396.

The Transport Month. T.W.A. has been cooperating with the Radio Corporation of America in experiments with the facsimile transmission of messages between airline radio station and tests of equipment on planes will be undertaken. Brief announcement only. Aviation, March 1936, page 96.

Wireless and Its Application to Commercial Aviation. J. M. Furnival. Functioning, limitations and possibilities of radio communication and direction-finding systems as used by the commercial air services, as well as problems facing designers and operators are discussed, under the headings of wave-length characteristics, communication, directional, and approach systems, design of aircraft and airport installations, control of radio for aviation and comparison of aeronautical and marine radio services. Discussion following presentation of paper is also included with the author's reply. Journal of the Royal Aeronautical Society, March 1936, page 159.

A Review of Radio Communication in the Fixed Services for the Year 1935. C. H. Taylor. Developments in point-to-point communication for commercial purposes during the year 1935, covering new national and international radio circuits, new stations and equipment, automatic operation of installations and equipment, and technical advances. Reference is made to the Pan American Airways network of eleven stations in Alaska and a chain of stations across the Pacific. Proceedings of the Institute of Radio Engineers, March 1936, page 390.

Navigation

True Blind Flight. L. deFlorez. Ears are capable of supplanting the eyes in blind flying according to the results of a series of experiments conducted by the author with an apparatus designed to produce and use sound as a reference in blind flying. The initial experiments dealt with sound-producing apparatus to obtain directional effect by shifting sound in ear phones and to determine sensitivity of the ears to changes in pitch, as well as the tendency of this sense to become dulled by fatigue. Experiments to determine whether the average ear could remember and return to a given pitch, and flight tests are also described. Journal of the Aeronautical Sciences, March 1936, page 168.

Meteorology

Aerial Navigation Through Clouds. The Formation of Ice. V. Pivetti. Observations of a pilot on a passenger airline over the Alps, regarding the formation of ice on airplanes flying through clouds. Internal and external characteristics of each type of cloud and their relation to ice formation are explained with suggestions to the navigator for avoiding ice formation. Rivista Aeronautica, February 1936, page 171.

Aeronautical Meteorology. W. R. Gregg. The two recent developments in meteorological service, discussed as of special significance to aeronautics, include the Commission on Aeronautical Meteorology organized by the International Meteorological Organization, and progress in the design of radio apparatus for measurement and reporting of upper-air conditions. Journal of the Aeronautical Sciences, March 1936, page 180.

Army Fliers Ignore Weather. Rockwell Field bombardment group, while admitting it has not solved the problem of hitting a fog-enshrouded target, is never deterred by fog or low-clouds from starting on daily bombing expedition. Brief reference only. Bulletin of the American Meteorological Society, February 1936, page 52.

Digests of Papers on Aircraft Operations. Use of Barometric Pressure for Setting Sensitive Altimeters in Airport and Airway Traffic Control, L. P. Harrison. Notes on the Technique of Landing Airplanes Equipped with Wing Flaps, M. N. Gough. Considerations of the Take-Off Problem, E. P. Hartman. Feasibility of Winds Aloft Observations at Sea, A. R. Stickley. Abstracts. Journal of the Aeronautical Sciences, March 1936, page 176.

Recent Gliding Performance and Their Meteorological Conditions. G. Walker. Gliding performance in England and Germany. Brief abstract from Nature, September 8, 1934, page 347. Bulletin of the American Meteorological Society, February 1936, page 51.

Progress in International Meteorology. W. R. Gregg. History of the International Meteorological Organization, radio applications in securing upper-air data, revision of the statutes of the I M O to meet the needs of aeronautics, and long-range weather forecasting are reviewed. Monthly Weather Review, December 1935, page 339.

Air Forces

AUSTRALIA

Australia's Air Defence. Present situation and plans for developing the Royal Australian Air Force. Flight, April 9, 1936, page 388.

GERMANY

Aerial Rearmament of Germany. General discussion of German rearmament with photographs and specifications of the Focke-Wulf Fw58 training plane. L'Aeronautique, February 1936, page 22.

Half and Half. Of the 2,000 military planes which Germany intends to build, half will be fighters and half bombers, the former being armed with three 20-mm. "canons" and six machine guns, while the bombers will each be allotted one "canon," one machine gun and about half a ton of bombs. Brief reference only. Flight, March 26, 1936, page 323.

GREAT BRITAIN

Air Force Developments. New types of planes, use of geodetic construction, and RAF personnel. Discussion by Sir Philip Sassoon when introducing the Air Estimates is quoted editorially. Engineering, March 27, 1936, page 349.

Introducing the Air Estimates. Statements of Sir Philip Sassoon in introducing the Air Estimates and discussing the proposed expansion of the Royal Air Force. The gross total is approximately 43 1/2 million and net total 39 million. Completion of the May program was designed to give the RAF a metropolitan strength of 123 squadrons with some 1500 first-line aircraft. Debate on the estimates is also quoted and is followed by a typical Grey discussion entitled "On Noises in the House." Aeroplane, March 25, 1936, page 372.

Matters of the Moment. Speculations regarding the British position in the Mediterranean in the event of war with Italy, with references to Italian deficiencies in armament and bombers. Aeroplane, March 11, 1936, page 307.

ITALY

Technical Notes. At the end of 1936 Italian airplanes will be increased to 5,500 modern airplanes of which 1500 will be bombers according to the present plan. Brief reference. Les Ailes, March 5, 1936, page 3.

JAPAN

Naval Airplanes. The Japanese Navy has no airplane in regular service with a speed of more than 178.5 mph. List is given of various types of planes used by the Navy with type of engine and the top and cruising speeds. U. S. Naval Inst., Proceedings, April 1936, page 587.

Air Warfare

Bombardment in Obscure Weather. C. Rougeron. Practical possibilities of bombardment from airplanes in obscure weather by means of aiming from a distant point of reference, or by means of regulation. From Revue du Ministere de l'Air, Nos. 10 and 11, 1935. Rivista Aeronautica, February 1936, page 205.

Fundamentals of Aerial Combat. V. Kusniescioff. Arming multiplace fighters with arms such as "canons" with large sectors of elevation is proposed. Maneuvering and firing from single-seater pursuit ships against light airplanes as well as in combat between multiplace pursuit ships and heavy planes are discussed. The command of aerial combats and some tactical and strategical questions of attacks in the air are taken up. Conclusion of article from Corriere della Flotta Aerea, July, 1935. Rivista Aeronautica, February 1936, page 220.

Determination of the Position of an Airplane in Space at a Given Moment. Captain Vauzon. Measurements of speeds and application to the control of sham bombardment. The SOM phototheodolite and method of estimation are described in detail, as well as the Desprez, Boulitte, and Jacquet apparatus and the S.I.O.P. precision optical comparator. A new method for determining flight speed by means of smoke, and its advantages in the estimation of ballistic bombardment are explained. Revue de l'Armee de l'Air, February 1936, page 137.

Miscellaneous

Back to Steam. Soviet engineers have decided that in order to reach greater heights more economically "stratoplanes" must be powered with steam engines or steam or gas turbines. The payload and range of a steam-engined airplane are thought to be twice those of the gasoline-engined plane. Brief reference only. Aeroplane, April 1, 1936, page 413.

Gaskets. F. C. Thorn. Gasketed joints are classified by types and materials. Constructions employed in modern gaskets for the various types of joints and for the various fluids handled through these joints are described. Formulas are given as a tentative basis for the design of flat flange joints. Industrial and Engineering chemistry, Industrial Edition, February 1936, page 164.

Light-Weight Anchor. Northill light-weight folding anchor developed by J. K. Northrop. Brief description. Aero Digest, April 1936, page 34.

Manufacturers of Accessories and Parts. Index and list of manufacturers and their products. Aero Digest, April 1936, page 146.

Accessories for 1936. Manufacturers of aircraft, airport, and engine accessories, and of aircraft materials and parts, are classified with brief outlines of products and company officials. Aviation, March 1936, page 51.

"The Aeroplane" at the British Industries Fair. Brief review of equipment of interest to the aircraft industry. Aeroplane, February 19, 1936, page 241. Flight, February 27, 1936, page 234.

Aptitude Testing. Personal experience with the Reid apparatus for testing the aptitude of fliers. Flight, February 20, 1936, page 198.

Institute of the Aeronautical Sciences Fourth Annual Meeting. M. Watter. Analysis of each paper presented emphasizing the more important points. Editorial on page 27 considers that members who are a part of government units took advantage of their government connection to impose upon the audience in presenting material which had been available to everyone for some time. Aero Digest, March 1936, page 27.